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YUNNAN-VIETNAM RAILWAY HERITAGE CORRIDOR: CONSTRUCTION, EVALUATION AND APPLICATION

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Abstract

In the current period of rapid development in China and Vietnam, the pressure from urbanization has posed considerable threats to historical railways and other kinds of industrial heritage, especially those heritages with large scales and extents. As a representative historical narrow-gauge railway in Southeast Asia, Yunnan-Vietnam Railway related to China, France and Vietnam, is selected as the research object in this study from an international perspective. From the literature review of Chinese railway heritage and site survey on Yunnan-Vietnam Railway, it is known that this old railway is of historical, technological, social-cultural, ecological, landscape and tourism values. But some of its sections have already been closed or destroyed, waiting for further protective solutions, along with crises, challenges and opportunities. With an increasing perception of railway heritage and railway tourism, a comprehensive and cooperative protection strategy is in need to document all the related relics along the Yunnan-Vietnam Railway, to assess its heritage value quantitatively and to support the tourism activities for its future redevelopment.

Meanwhile, spatial technologies have been evolved rapidly since their birth, connected more closely with history and archaeology, and applied to more practical cases and fields. GIS combined with RS and GPS is proved to have adequate supports in the protection for both cultural and natural heritage, for its advantages in spatial processing, analyzing, managing and information interpreting and sharing. This research, from a geo-historical perspective, mainly utilizes Historical-GIS as methodology based on the historical and geographical backgrounds of CFY, which integrates spatial technologies with multiple disciplines, especially the concept of heritage corridor. It discusses a solution for the protection and management of large-scale heritage through multi-level geo-analysis and applications. The original historical documents conserved in archives (historical photos, maps, etc.), along with other open spatial data, big data and fieldwork data were collected, systemized and used to build a heritage database. These movable documents are considered as a part of the CFY heritage, and the application of historical images into CFY study makes it groundbreaking.

After building a geodatabase in form of GeoPackage, GIS is combined with Analytic Hierarchy Process, Delphi Expert Method and Minimum Cumulative Resistance Model as a spatial integrated method for the construction and evaluation of CFY heritage corridor. Some objectives are fulfilled, including effective heritage management, regional coordination under various authorities, data shareability with other users and researchers and the supports for heritage tourism. Besides, an assessment tool for railway heritage corridor is introduced and updated based on previous research, discussing the indicators influencing heritage value of historical railway from five aspects: technology, social-culture, ecology, landscape and tourism. In this built heritage corridor, all the dedicated heritage resources are classified, and a spatial pattern of the corridor is also analyzed. As a result, more spatial applications are fulfilled on basis of the built heritage corridor and the calculated heritage value of the whole railway area, which refers to basic mapping of the heritage area, heritage visualization with WebGIS, geo-historical changes along the railway and data sharing through the ArcGIS server. At last, some suggestions based upon the study of CFY heritage are discussed and proposed for the future research on the protection and management of railway heritage in China.

Keywords: Yunnan-Vietnam Railway; Railway heritage; Spatial technologies; Historical GIS; Railway tourism

Abbreviations

3S: GIS, RS and GPS

AIA: The Association for Industrial Archaeology

AMS: Army Map Service

ANOM: Archives nationales d'outre-mer

AR/VR: Augmented Reality/ Virtual Reality

ARIH: Asian Route of Industrial Heritage

ASEAN: Association of Southeast Asian Nations

BIM: Building Information Modelling

CCI: Chambre de commerce et d'industrie

CEPF: The Critical Ecosystem Partnership Fund

CER: Chinese Eastern Railway

CFY: Chemins de fer de l'Indochine et du Yunnan

CHGIS: Chinese Historical Geographic Information System

CI: Conservation International

CIESIN: Center for International Earth Science Information Network

CIY: Compagnie française des chemins de fer de l'Indochine et du Yunnan

CNKI: China National Knowledge Infrastructure

CSV: Comma-separated values

CSS: Cascading Style Sheets

DHR: Darjeeling Himalayan Railway

EC: European Commission

ECR: European Cultural Route

ERIH: European Route of Industrial Heritage

ESA: European Space Agency

ESCAP: United Nations Economic and Social Commission for Asia and the Pacific

ESRI: Environmental Systems Research Institute

EPA: Environmental Protection Agency

FAO: Food and Agriculture Organization

FEDECRAIL: European Federation of Museum & Tourist Railways

FICCIM: Conservation of Industrial Monuments

Gebishi: Gejiu- Bisezhai- Shiping Railway

GIS: Geographic Information System

GMS: Greater Mekong Subregion

GNSS: Global Navigation Satellite Systems

GPS: Global Positioning System

GrassGIS: Geographic Resources Analysis Support System

HTML: Hypertext Markup Language

IA: Industrial Archaeology

ICCROM: International Centre for the Study of the Preservation and Restoration of Cultural Property

ICOMOS: International Council on Monuments and Sites

IH: industrial Heritage

ISEAS: Institute of Southeast Asian Studies in Singapore

IUCN: International Union for Conservation of Nature

KMGHJ: Kunming Urban Planning Bureau

KRB: Kunming Railway Bureau

LC-CCI: Land cover/ Climate Change Initiative

LIDAR: Light Intensity Detection and Ranging

LULC: Land use/land cover

MCRM: Minimum Cumulative Resistance Model

MODIS： Moderate Resolution Imaging Spectroradiometer

NASA: The National Aeronautics and Space Administration

NDVI: Normalized difference vegetation index

OGC: Open Geospatial Consortium

OSM: Open Street Map

OUV: outstanding universal value

PNT: position, navigation and timing

POI: Point of interests

RDMS: Relational database management system

RS: Remote Sensing

SBD: Spatial big data

SCP: Semi-Automatic Classification Plugin

SEDAC: Socioeconomic Data and Applications Center

SRHGIS: Silk Road Historical Geography Information Open Platform

SIA: Society for Industrial Archeology

SQL: Structured Query Language

SRHGIOP: Silk Road Historical Geography Information Open Platform

SRTM: Shuttle Radar Topography Mission

TICCIH: The International Committee for the Conservation of the Industrial Heritage

TLS: Territorial Laser Scanning

UAV: Unmanned Aerial Vehicle

UNESCO: United Nations Educational, Scientific and Cultural Organization

UK: United Kingdom

USA: United States of America

UTM: Universal Transverse Mercator

VNM: Viet Nam

VNRA: Viet Nam Railway Authority

WHC: World Heritage Centre

WWII: The Second World War

WWW: World Wide Web

YBR: Yunnan-Burma Railway

YN: Yunnan

YRA: Yunnan Railway Administration

List of Figures

Figure. 124 Sharing data on ArcGIS online

Source:https://www.arcgis.com/home/item.html?id=31179cfdc8454d2c987015400292b070#

List of Tables

Table. 1 Inscribed sites in the first Chinese National List of Industrial Heritage (2018)

ID	Name	Year	Type of industry
1	Zhangyu brewing company	1892	Brewing industry
2	Anshan iron and steel plant	1880	Iron and Steel
3	Lushun dock	1890	Transportation- shipping
4	Jingde cosmic porcelain factory	1949	Manufacture
5	West Huashan Tungsten	1908-1938	Mining
6	Benxi Lake coal and iron company	1905-2005	Iron and Steel
7	Baoji Shenxin mill factory	1940	Manufacture
8	Wenzhou alum mine	1956-1998	Mining
9	Linghu silk factory	1946	Manufacture
10	Heavy steel plant in Chongqing	1938	Iron and Steel
11	Hanyepin company	1908	Iron and Steel and mine

Source: http://www.planning.org.cn/news/uploads/2019/04/5cb0447996966_1555055737.pdf

Table. 2 Comparison among railway heritages in the World Heritage List

Railway name	Year	Length (km)	Max. alt. (m)	Max. slope (%)	Width (mm)	Way of climbing	Character
Bernina	1903	127	2253	7.0	1000	U-turn/ Loop	mountain
Semmering	1854	41	895	2.5	1435	U-turn	mountain
Darjeeling	1881	88	2258	5.5	610	4 types[1]	mountain
Kalka Shimla	1903	96.60	2075		762	U-turn	mountain
Nilgiri	1908	46	2203		1000	U-turn/ Rack rail	mountain

Source: Su, C. (2011). Research on Universal Value of Alishan Forest Railway in Survey of UNESCO World Culture Heritage Railways. Journal of Humanities Research, 9, 135-165.

[1] U-turn, loop and spiral, switch back and special engine

Table. 3 Comparison of academic attention among five railway heritages in China

Name	Tang-Xu	CER	CFY	Jing-Zhang	Jiao-Ji
Total Literature	37	529	422	374	398
Heritage studies	5	218	54	30	25
10-year increase	0	39	6	0	1
Media attention	14	99	178	126	229
Total citations[2]	22	442	119	48	40

[2] Based on the searching results from CNKI database (Search time: 2018/10/05)

Table. 4 Information on seven railway heritages in China

Name	Year	Width (mm)	Length (km)	Location	Constructor
Tang-Xu	1881	1435	9	Hebei	Britain
CER	1897	1524	2400	North	Russia
CFY	1903	1000	855	Yunnan	France
Jing-Zhang	1905	1435	201	Hebei	China
Ba- shi	1959	762	20	Sichuan	China
Jiao-Ji	1899	1435	393	Shandong	Germany
Bao-Cheng	1952	1435	668	Shannxi	China

Source: Jiang, P., Shao, L., & Baas, C. (2019). Interpretation of Value Advantage and Sustainable Tourism Development for Railway Heritage in China Based on the Analytic Hierarchy Process. *Sustainability*, 11(22), 6492.

Table. 5 Touristic records and scores of Yunnan-Vietnam Railway attractions

Touristic sites	**Ranking**	**Comments**	**Score**
Yunnan Railway Museum	19/212	24	4.5/5
Bisezhai railway Station	6/21	1	4.0/5
Namti Bridge	2/6	0	0
Seven Hole Bridge	1/13	2	4.0/5
China-Vietnam Railway Bridge	2/11	7	4.0/5
Longbien Bridge	44/305	988	4.0/5

Source: https://cn.tripadvisor.com/Tourism-g297467-Yunnan-Vacations.html

Table. 6 Keywords analysis of tourists' comments on CFY

Type	Positive description		Negative description	
Nature Landscape	Forest	Mountain	Pedestrian danger	Mining
	Karst landform	tropical style		
	River creek/ waterfall	height difference change		
	Mysterious Exploration of Nature	Winding route	Pollution	Hot climate
Cultural landscape	Engineering miracles	Minority customs	Management problem	Abandoned/ destruction
	Cultural exchanges	Border trade	Poverty	Poor accessibility
	French architecture	Historic meaning	Wars	Tourists attraction

Source: http://www.mafengwo.cn/search/q.php?q=滇越铁路

Table. 7 Foreign explorations in Southeast Asia

Time	Leading person	Nationality	Area	Field
1867-1868	T. T. Copper	U.K.	Yangtze River, Yunnan	comprehensive
1868	E. B. Sladen	U.K.	Yunnan	Commercial
1877	W. J. Gill/ W. Mesny	U.K.	Sichuan-Yunnan - Burma	Geology
1885	Paul Vial	France	Yunnan	Anthropology
1885-1886	F. S. A. Bourne	U.K.	Yunnan, Guizhou	Commercial
1894-1900	H. R. Davis et al.	U.K.	Yunnan	Geology/Anthropology
1910	Jacques Deprat	France	Laos, Vietnam, Yunnan	Geology
1913-1914	F. Kingdon.Ward	U.K.	Yunnan	Hydrology/ biology
1922	Joseph F. C. Rock	USA	Yunnan, Tibet	Geography/ Biology
1883-1896	J. M. Delavay	France	Yunnan	Biology
1887-1915	Samual Pollard	U.K.	Yunnan	Anthropology
1904-1932	G.Forrest	U.K.	Yunnan	Biology
1899-1901	Augste Francois	France	Yunnan	comprehensive
1930-1931	Edgar Snow	USA	Yunnan, Burma	comprehensive
1933-1938	C. P. FitzGerald	U.K.	Yunnan, Burma, India	Anthropology

Source: Yang, M. (2011). The exploratory activities of in modern times by westerners in Yunnan and their works. PhD dissertation of Yunnan University, pp 22-56.

Table. 8 Population changes along the CFY[3]

City Name	1910	1932	2000	2010
Kunming	85000	143700	5781294	6432209
Chenggong	51584	77526	180685	310843
Yiliang	64865	110706	396677	419399
Kaiyuan	54602	96408	292039	322693
Jianshui	179659	198165	513712	531456
Mengzi	60912	131587	340051	417156
Gejiu	10682	93586	453311	459781
Chengnjiang	51547	70389	149748	169366
Maguan	151771	197374	350002	367507
Huaning	70066	97206	196519	214650
Pingbian	49535	72812	149088	153964
Mile	57365	113918	495642	539725
Hekou	No data	No data	95451	104609

Source: Yunnan maps from the Library of Congress in USA

[3] Historical population data of the regions in Vietnam are lacking.

Table. 9 Organizations and their conserved photographic documents

Name of organization	Contents of documents
Archives Nationales d'Orere-mer in Provence	Elevation map of railway stations; railway route design maps; construction drawings
Archive of Mulhouse	Photographic album recording the construction; elevation map of railway stations and the whole area; films and original negatives
Musée national des Arts asiatiques-Guimet	Photos taken by Auguste Marbotte and Auguste François
Institute of Southeast Asian Studies	Photos taken by Albert Marie
University of Texas Libraries	U.S. Army Map Service provides land use map of Yunnan and Vietnam made in 1954
Ecole nationale des ponts et chaussées	Photos in the official book of CIY; Design of bridges, locomotive, tunnels and railway stations; maps of Yunnan

Table. 10 Photographers of CFY

Photographer	Position	Time	Source	Quantity
A. Marbotte	Accountant	1903-1908	Musée Guimet	Nearly 2000
A. Marie	Engineer	1904-1906	Institute of Southeast Asian Studies in Singapore	138
A. François	French consul	1899-1904	Musée Guimet	Nearly 1600
Têtard René and Busy Léon	Unknown	1919-1926	Archives Nationales d'Orere-mer of Provence (online)	24

Table. 11 Historical photos and maps used for this research

Photographer	**Source**	**Quantity**	**Year**
G. A. Marbotte	Book: Un chemin de fer au Yunnan: L'aventure d'une famille française en Chine (published)	54 photos	1903-1908
A. Marie	Two published articles[4]	33 photos	1904-1906
A. François	Book: A Record of Kunming's Social Features in the Late Qing Dynasty and Early Republic of China	103 photos[5]	1899-1904
CIY	Photographic album in Archive of Mulhouse	759 photos	1906-1913
USA army	University of Texas Libraries (online)	11 maps	1954
Yunnan Department of Civil Affairs	Library of Congress in USA	14 maps	1944
Têtard René; Busy Léon	Archives Nationales d'Orere-mer of Provence (online)	24 photos	1919-1926

[4] Source: Bernaed O. Locard E. (2013). Le chemin de fer du Yunnan: Un jeune ingénieur français en route de Saigon à Yleang. *Images &memories*, 37, 19-26.

Pholsena, V. (2015). Technology and Empire: A Colonial Narrative of the Construction of the Tonkin Yunnan Railway. *Critical Asian Studies*, 47(4), 537-557.

[5] The photos taken by François in the archive are hard to identify, thus, this research uses the photos interpreted by historians and published in the book already.

Table. 12 Parameters of Sentinel 2-A sensor

Band	Name	Wavelength (μm)	Resolution (m)
1	Coastal	0.430-0.457	60
2	Blue	0.440-0.538	10
3	Green	0.537-0.582	10
4	Red	0.646-0.684	10
5	Red edge	0.694-0.713	20
6	Red edge	0.731-0.749	20
7	Red edge	0.769-0.797	20
8	NIR	0.760-0.908	10
8A	Red edge	0.848-0.881	20
9	Water	0.932-0.958	60
10	Cirrus	1.337-1.412	60
11	SWIR	1.539-1.682	20
12	SWIR	2.078-2.320	20

Source:
https://semiautomaticclassificationmanual.readthedocs.io/en/latest/remote_sensing.html#basic-definitions

Table. 13 Sources of online GIS data

Website	Content	Data format
DIVA GIS	administrative divisions; inland water; rivers; lakes; roads; railroads	Vector
Natural Earth Data	populated places; urban areas; parks	Vector
Greater Mekong Subregion	basin regions; protected areas; airports; seaports; soil classification; economic cities; tourism cities; minority groups	Vector
World Clim	temperature; rainfall	Raster
Socioeconomic Data and Applications Center	Global population density, mineral resources,	Raster
Center for International Earth Science Information Network	Economic and population data	Excel table
Center for International Earth Science Information Network	Disaster (earthquake and landslide)	Raster/vector
Earth Explorer	Sentinel-2 satellite images; Digital Elevation Model data (DEM)	Raster
Global Forest Watch	Biodiversity significance; forest cover; cropland	Raster
Land cover CCI viewer	Global land cover (2009;2015)	Raster
Earth data (NASA)	MODIS Land Cover- Product MCD12Q1 (2001;2018)	Raster

Table. 14 Sources of spatial big data

Website	Content	Format	Way of collection	Quantity
Flicker and Weibo	Popular touristic sites in study area of Yunnan	Vector (point)	Collector (Houyi)	3960
Flicker and Weibo	Popular touristic sites in study area of Vietnam	Vector (point)	Collector (Houyi)	22976
Baidu map	Touristic services in Yunnan (Restaurant, hotel and hospital)	Vector (point)	Collector (Ebay)	1028
Open street map	Touristic services in Vietnam (Restaurant, hotel and hospital)	Vector (point)	Collector (Ebay)	1806
Baidu map	Scenic spots in study area (parks, mountains, historical monuments, scenic resorts)	Vector (point)	Collector (Ebay)	300
Open street map	Stations, tunnels and bridges of CFY	Vector (point)	Collector (Ebay)	274

Table. 15 An example of the description of metadata of fieldwork photos

Metadata	**Description (An example)**
ID	01
Title	IMG_4089
Longitude	106.688 E
Latitude	20.856 N
Altitude	1350 m
Source	Railway site
Creator	Kun Sang
Copyright	Kun Sang
Shooting data/ time	2018/09/22 18:03
Device	iPhone SE
Storage path	Computer/

Table. 16 Evaluation system for the Chinese industrial heritage

Value	**Indicator**	**Classification/ Score**				
Historical	Age	<1911	1911-1948	1949-1956	1966-1976	
		10	8	6	3	
	Historical relevance	A	B	C	D	
		10	6	3	0	
Technological	Groundbreaking	A	B	C	D	
		10	6	3	0	
	Engineering	A	B	C	D	
		10	6	3	0	
Social-cultural	Social emotion	A	B	C	D	
		10	6	3	0	
	Company culture	A	B	C	D	
		10	6	3	0	
Aesthetic	Architectural aesthetics	A	B	C	D	
		10	6	3	0	
	Overall landscape	A	B	C	D	
		10	6	3	0	
Economic	Reuse of Structure	A	B	C	D	
		10	6	3	0	
	Reuse of space	A	B	C	D	
		10	6	3	0	
Location	Location advantage	A	B	C	D	E
		15	10	5	0	-3
	Traffic condition	A	B	C	D	E
		15	10	5	0	-2
Building quality	Structural safety	A	B	C	D	E
		15	10	5	0	-3
	Integrity	A	B	C	D	E

		15	10	5	0	-2
Reuse value	Reuse of space	A	B	C	D	E
		15	10	5	0	-3
	landscape reuse	A	B	C	D	E
		15	10	5	0	-2
Technical feasibility	Reuse feasibility	A	B	C	D	E
		15	10	5	0	-3
	Feasibility for Maintenance	A	B	C	D	E
		15	10	5	0	-2

Source: Liu, B., & Li, K. (2006). The composition and value evaluation method of industrial heritage. *Architectural creation*, 9, 24-30.

Table. 17 Criteria for the evaluation system for CFY heritage

Target (A)	Indicators (B)	Index (C)	ID	References
CFY heritage evaluation (A)	Landscape (B1)	Scenic spots	C1	Brunsden, 1979; Tudor, 2019; Martín et al, 2016;
		Visibility	C2	
		Stream density	C3	
	Ecology (B2)	Vegetation (NDVI)	C4	Ying et al, 2007; Yu et al, 2011
		Naturalness	C5	
		Biodiversity	C6	
	Technology (B3)	Historical richness	C7	Tveit et al, 2007; Jiang et al, 2019
		Engineering difficulty	C8	
		Climate suitability	C9	
	Social culture (B4)	Population density	C10	Xiong et al., 2007
		Cultural diversity	C11	
		Economy growth	C12	
	Tourism (B5)	Touristic services	C13	HE, 2011; Gnanapala, 2015
		Accessibility	C14	
		Popularity	C15	

Table. 18 Correlation for each pair of indexes

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14
C2	-0.19													
C3	-0.03	-0.14												
C4	-0.04	0.07	0.04											
C5	0.02	0.19	0.10	0.12										
C6	-0.13	-0.10	0.31	0.22	0.15									
C7	0.12	0.07	-0.24	-0.26	0.13	0.20								
C8	-0.02	0.16	-0.13	0.18	0.15	0.42	0.52							
C9	-0.05	-0.12	0.52	0.22	-0.12	-0.05	-0.73	-0.38						
C10	0.22	-0.16	0.24	-0.32	-0.17	-0.44	-0.37	-0.68	0.37					
C11	0.17	-0.15	0.46	-0.19	-0.06	-0.22	-0.18	-0.44	0.40	0.72				
C12	0.06	0.08	-0.51	-0.36	0.05	-0.29	0.65	0.21	-0.83	-0.12	-0.14			
C13	0.34	-0.14	0.01	-0.04	0.05	0.31	-0.04	-0.32	0.02	0.48	0.50	0.18		
C14	0.17	-0.10	0.31	-0.03	-0.12	0.03	-0.25	-0.38	0.36	0.55	0.48	-0.35	0.31	
C15	0.42	-0.02	0.21	-0.25	0.02	0.01	0.10	-0.18	0.05	0.47	0.61	0.08	0.62	-0.11

Table. 19 Explanation of each index

Index	Explanation	Class (score)	Data
Scenic spots (C1)	If a place is closer with a scenic spot, it has a higher landscape value. It is evaluated by the distance with the scenic spots.	5, Distance < 50 m 4, 50 m < Distance < 150 m 3, 150 m < Distance < 1000 m 2, 1000 m < Distance < 5000 m 1, Distance > 5000 m	Vector of Scenic_places
Visibility (C2)	Based on the railway stations, the viewshed is calculated within a distance of 10 km. The viewshed is classified by the distance with the station.	5, Distance < 50 m 4, 50 m < Distance < 150 m 3, 150 m < Distance < 1000 m 2, 1000 m < Distance < 5000 m 1, Distance > 5000 m	Raster of Elevation (DEM), Vector of stations
Stream density (C3)	River landscape is a main aesthetic object of the CFY tour. A place with higher stream density has a higher landscape value. It is calculated by the tool of “line density”.	1, Density < 0.079 2, 0.079 < Density < 0.098 3, 0.098 < Density < 0.117 4, 0.117 < Density < 0.145 5, Density > 0.145 (Unit: /km^2)	Vector of River
Vegetation (NDVI) (C4)	NDVI is an index to reflex the coverage of live green vegetation. A higher value of NDVI means a higher ecological value in the study area.	1, NDVI < 0.155 2, 0.155 < NDVI < 0.244 3, 0.244 < NDVI < 0.338 4, 0.338 < NDVI < 0.481 5, NDVI > 0.481	Raster of NDVI based on the Sentinel-2 data

Naturalness (C5)	Based on the land cover type, the naturalness of a land is classified into five classes. A more natural land cover has a higher ecological value and an artificial land has a lower value.	1, Urban area 2, Bare area 3, Grassland 4, Shrubland 5, Forest	Raster of Landcover_2015
Biodiversity (C6)	Based on the biodiversity importance value classified by the IUCN. A place with higher biodiversity importance means a higher ecological value.	1, value: 0-1 2, value: 1-4 3, value: 4-5 4, value: 5-7 5, value > 7	Raster of Bio_importance
Historical richness (C7)	The density of historical remains shows its historical richness. In this indicator, the density of railway heritage is used to calculate the heritage density by the tool of Kernel Density Estimation.	1, Density < 0.307 2, 0.307 < Density < 1.539 3, 1.539 < Density < 5.233 4, 5.233 < Density < 19.395 5, Density > 19.395 (Unit: /km^2)	Vector of Railway_heritage and Historic_photos
Engineering difficulty (C8)	Slope is the main indicator for the engineering difficulty. Based on the DEM data, the slope is calculated, and then classified into five classes	1, slope < 4.696 2, 4.696 < slope < 10.531 3, 10.531 < slope < 17.442 4, 17.442 < slope < 25.855 5, slope > 25.855 (Unit: degree)	Raster of DEM and Slope_degree

Climate suitability (C9)	The climatic condition was also another difficulty for the railway construction. Thus, in this indicator, the average temperature in august is selected to evaluate the climate suitability of railway construction.	1, Temp < 20.091 2, 20.091 < Temp < 21.590 3, 21.590 < Temp < 25.782 4, 25.782 < Temp < 27.984 5, Temp > 27.984 (Unit: °C)	Raster of Temp_08
Population density (C10)	A higher population density means that the railway was serving for more people in this area, thus with a higher social-cultural value.	1, Density < 20 2, 20 < Density < 150 3, 150 < Density < 500 4, 500 < Density < 1000 5, Density > 1000 (Unit: person/km^2)	Raster of Population_density (2020)
Cultural diversity (C11)	The density of historical cities/ towns and ethnic villages reflects the cultural diversity in this area, a higher cultural diversity means a higher social-cultural value. The density is calculated by Kernel Density Estimation.	1, Density < 0.082 2, 0.082 < Density < 0.306 3, 0.306 < Density < 0.621 4, 0.621 < Density < 1.068 5, Density > 1.068 (Unit: /km^2)	Vector of Ethnic_groups
Economic growth (C12)	The area with a higher economic growth means a higher potential for the development and the social-cultural value.	1, Rate < 12.96% 2, 12.96% < Rate < 13.11% 3, 13.11% < Rate < 13.46% 4, 13.46% < Rate < 13.89% 5, Rate > 13.89%	Raster of Economic_growth

Touristic services (C13)	The density of touristic services (restaurants, hotels and hospitals) is calculated to show the tourism value in this area, by the by Kernel Density Estimation tool.	1, Density < 0.290 2, 0.290 < Density < 0.871 3, 0.871 < Density < 3.192 4, 3.192 < Density < 16.831 5, Density > 0.621 (Unit: /km^2)	Vector of Public_services
Accessibility (C14)	The density of road system shows the accessibility of an area. It is calculated by the line density tool. A higher degree of accessibility means a higher tourism value.	1, Density < 0.048 2, 0.048 < Density < 0.071 3, 0.071 < Density < 0.092 4, 0.092 < Density < 0.118 5, Density > 0.118 (Unit: /km^2)	Vector of Road_system
Popularity (C15)	A place is more popular among tourists means a higher value of tourism. In this indicator, the photo from social media is collected to show the popularity of a place by the density of these photos.	1, Density < 2.361 2, 2.361 < Density < 2.721 3, 2.721 < Density < 5.443 4, 5.443 < Density < 21.775 5, Density > 21.775 (Unit: /km^2)	Vector of Popular_sites

Table. 20 Relative importance comparison between each two indexes

Value	Importance	Value	Importance
i:j= 1/1	same importance	1/1	same importance
i:j = 3/1	slightly more important	1/3	slightly less important
i:j = 5/1	more important	1/5	less important
i:j = 7/1	much more important	1/7	much less important
i:j = 9/1	extremely more important	1/9	extremely less important
i:j = 2*n/1*	n=1,2,3,4, the importance between (1-9)	1/2n	n=1,2,3,4, the unimportance between (1-1/9)

Table. 21 Result of the questionnaire for experts

Indicator	Comparison of two indexes	Result
Landscape (B1)	Scenic spots VS Visibility	1
	Visibility: VS Stream density	3
	Stream density VS Scenic spots	1/3
Ecology (B2)	Vegetation (NDVI) VS Naturalness	1/3
	Naturalness VS Biodiversity	1/2
	Biodiversity VS Vegetation (NDVI)	6
Technology (B3)	Historical richness VS Engineering difficulty	1/3
	Engineering difficulty VS Climate suitability	5
	Climate suitability VS Historical richness	1/3
Social culture (B4)	Population density VS Cultural diversity	1/4
	Cultural diversity VS Economy growth	2
	Economy growth VS Population density	3
Tourism (B5)	Touristic services VS Accessibility	1/3
	Accessibility VS Popularity	4
	Popularity VS Touristic services	1/3

Table. 22 Weight of each index

Indicator	Index	Weight
Landscape (B1)	C1	42.86%
	C2	42.86%
	C3	14.29%
Ecology (B2)	C4	10%
	C5	30%
	C6	60%
Technology (B3)	C7	26.50%
	C8	63.33%
	C9	10.62%
Social culture (B4)	C10	12.26%
	C11	55.71%
	C12	32.02%
Tourism (B5)	C13	27.21%
	C14	11.99%
	C15	60.80%

Table. 23 Original raster value and the rule of reclassification

Original value	Land cover type	Reclassified value	Reclassified type
1	Evergreen Needleleaf Forests		
2	Evergreen Broadleaf Forests		
3	Deciduous Needleleaf Forests	1	Forest
4	Deciduous Broadleaf Forests		
5	Mixed Forests		
6	Closed Shrublands		
7	Open Shrublands		
8	Woody Savannas	No data	No data
9	Savannas		
10	Grasslands		
11	Permanent Wetlands		
12	Cropland	2	Cropland
13	Urban and Built-up	3	Urban area
14	Cropland/Natural Vegetation Mosaics		
15	Snow and Ice	No data	No data
16	Barren		
17	Water body	4	Water body

Source: https://lpdaac.usgs.gov/products/mcd12q1v006/

Table. 24 Land use change in CFY counties (Yunnan)

Land use	**County**	**Area (km^2)**			**Change rate**	
		1954	2001	2018	1954-2001	2001-2018
Cropland	Chenggong	105.63	75.02	14.00	-0.29	-0.81
Forest		1.53	41.88	62.31	26.37	0.49
Urban		0.00	101.06	120.21	+	0.19
Water		144.81	130.73	129.85	-0.10	-0.01
Cropland	Chengjiang	91.25	135.18	73.11	0.48	-0.46
Forest		12.23	33.94	62.83	1.77	0.85
Urban		0.56	31.57	37.48	55.38	0.19
Water		135.50	122.84	121.09	-0.09	-0.01
Cropland	Gejiu	72.86	109.81	96.38	0.51	-0.12
Forest		76.00	136.30	150.08	0.79	0.10
Urban		1.58	60.32	61.63	37.17	0.02
Water		5.65	1.13	1.13	-0.80	0.00
Cropland	Hekou	0.00	10.88	17.48	+	0.61
Forest		292.48	184.03	319.14	-0.37	0.73
Urban		0.00	3.88	3.88	+	0
Water		0.00	0.00	0.54	0	+
Cropland	Huaning	90.36	271.34	106.83	2.00	-0.61
Forest		66.26	119.93	118.85	0.81	-0.01
Urban		0.75	25.44	25.87	32.91	0.02
Water		19.46	14.54	13.66	-0.25	-0.06

Cropland	Jianshui	224.15	551.09	410.94	1.46	-0.25
Forest		527.53	504.66	518.90	-0.04	0.03
Urban		1.78	45.41	50.94	24.51	0.12
Water		4.17	1.32	0.88	-0.68	-0.33
Cropland	Kaiyuan	78.87	425.75	442.38	4.40	0.04
Forest		270.58	162.18	166.79	-0.40	0.03
Urban		0.96	64.28	66.46	65.96	0.03
Water		1.43	0.00	0.00	-1.00	0
Cropland	Kunming	163.66	61.86	23.04	-0.62	-0.63
Forest		36.83	135.79	179.46	2.69	0.32
Urban		4.87	357.62	391.23	72.43	0.09
Water		60.06	18.68	16.93	-0.69	-0.09
Cropland	Maguan	40.28	19.31	9.83	-0.52	-0.49
Forest		161.41	263.79	535.12	0.63	1.03
Urban		0.00	10.97	16.68	+	0.52
Water		0.67	0.00	0.00	-1.00	0
Cropland	Mengzi	202.67	274.09	177.90	0.35	-0.35
Forest		51.18	117.66	157.24	1.30	0.34
Urban		0.96	76.17	86.70	78.34	0.14
Water		16.87	10.72	9.84	-0.36	-0.08

Cropland	Mile	219.86	939.89	872.83	3.27	-0.07
Forest		408.32	217.76	303.87	-0.47	0.40
Urban		1.69	43.44	47.83	24.70	0.10
Water		0.70	2.63	3.07	2.76	0.17
Cropland	Pingbian	6.64	15.70	277.42	1.36	16.67
Forest		84.74	412.30	454.67	3.87	0.10
Urban		0.00	3.07	3.07	+	0.00
Water		0.00	0.00	0.00	0	0
Cropland	Yiliang	124.57	672.22	386.19	4.40	-0.43
Forest		289.69	170.81	254.50	-0.41	0.49
Urban		0.47	55.72	57.96	117.56	0.04
Water		15.44	8.62	8.62	-0.44	0.00

Table of Contents

Introduction

After the Industrial Revolution, post-industrial period came along with old habitats of traditional industries abandoned, relocated, or underused, left tremendous sites with industrial remains waiting for renewing and redeveloping (Adams & Watkins, 2008). However, due to the population and urban pressure during the urban renewal, those remains have always been overlooked or destroyed. Some of these sites were successfully turned into theme parks, museums, mixed-use districts or green infrastructures after the measures of landscape renovation. But other transformations lacking for scientific analysis just intensified the destruction of these potential heritages. This problem left into the 21st century: the unidentified industrial relics are still vulnerable, and the protection of industrial heritage remains presently urgent. In developing countries, especially, dealing well with the relationship between protection and redevelopment of industrial heritage is still a challenge.

As a kind of industrial heritage, railway gained early attention from the public and scholars for its multiple values in heritage tourism. Still, in the World Heritage List[6], there are limited historical railways inscribed, which are facing similar problems with other industrial heritages. Against this background, this thesis focuses on a representative historical railway in Southeast Asia[7], namely the Yunnan-Vietnam Railway (CFY)[8], to conduct a research on railway heritage protection, management

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6 Cultural and natural heritage sites administered by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

7 Geographically, China belongs to the Eastern Asia, but Yunnan province in China has more connections with the Southeast Asian countries.

8 Also named Indochina-Yunnan railway or Kunming-Haiphong railway, it has also other names or translations. In this thesis, it is called as "Yunnan-Vietnam railway" in English, while in Chinese "滇越铁路", and in French "Chemins de fer de l'Indochine et du Yunnan", in Vietnamese

and redevelopment. CFY (figure 1) is one of the earliest built railways in Vietnam and the longest narrow-gauge railway well-known in China. The whole railway system connects China with Vietnam under various authorities. Passing through mountainous territory, CFY was considered as a miracle in the history of engineering, witnessed the changing relations between the Occident and the Orient (Rousseau, 2004). Currently, this complex heritage system links a large number of physical relics, scenic spots, urban landscapes, key ecological areas, ethnic villages, as well as other related intangible and movable heritages.

Figure 1, A symbol of CFY - Namti Bridge (now and before)

"Tuyến đường sắt Hải Phòng - Vân Nam". The abbreviation "CFY" is according to its original French name.

As substantial evidence of Asian industrial history and railway culture, the related governments are trying to cooperate to apply for a joint World Heritage for the linear area of Yunnan-Vietnam Railway and to redevelop the related touristic resources for regional economy. Its authenticity and integrity should be passed and inherited to the next generations not only for China and Vietnam but for the whole human civilization. Lots of research and scholars have been involved from various perspectives and topics on CFY studies. Abundant results have already been published in Chinese, especially by the organizations in Yunnan province; its outstanding values have also been widely recognized. But there are still many original historical documents conserved in the archives in France which have not been studied yet, and the section in Vietnam is always in a neglected status. This historical railway is still facing a series of opportunities and challenges for its future. How to protect and redevelop those underused CFY heritages and to handle the future of once-thriving railway regions under a cooperation among Yunnan, France and Vietnam in the present age is a question hanging there.

To solve this problem, Geographical information system (GIS) is introduced combined with other spatial technologies (Remote Sensing, Global Positioning System and Digital Cartography), to investigate, evaluate and manage the CFY heritages from a broader spatial scale and in-depth historical context. From this central research question, there will contain four related topics discussed in detail in this thesis:

i) What is the historical development of the Yunnan-Vietnam railway, its regional geographic conditions, the current situation of protection, and the problems and opportunities it is facing?

ii) What are the main values of historical railways as a heritage and their attractions in heritage tourism?

iii) Based on the historical and geographical understandings of the CFY regions, how can it be fulfilled the combination of abundant geo-historical data in the heritage database of CFY?

iv) How to integrate the spatial technologies with the railway heritage to build the CFY heritage corridor system, and based on the established system to support further heritage evaluation, interpretation and tourism activities?

CHAPTER 1. RESEARCH BACKGROUND

1.1 Purpose of the study

1.1.1 Importance of the study

Yunnan-Vietnam Railway, constructed in the 1900s according to the civic development plan of French Indochina, has a history for more than 110 years[9]. The whole railway started from Kunming (capital of Yunnan in China), via Yiliang, Kaiyuan, Bisezhai, Hekou and other historical cities and villages, extending to Laocai and Hanoi (capital of Vietnam), terminating in Haiphong (one of the largest ports in Southeast Asia). The Chinese section has a length of 465 km and in Vietnam 389 km[10]. Functioned as a colonial transportation method for invading and plundering Asia, it also played a significant role as a historical corridor for cultural and commercial exchanges between Yunnan and Vietnam, improved the connectivity and communication in Southeast Asia (Duong, 2014). Throughout the century after its construction, CFY had witnessed a series of modern revolutions such as the WWII and Sino-Vietnamese War, reflected the pace from conflicts towards cooperation and prosperity. The value of this railway lies not only in its cultural and revolutionary history, but also in the engineering techniques used for constructing the mountainous

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[9] The Vietnamese section started the construction in 1901 and Chinese section was begun from 1903.

[10] There are different records and discussions on the whole length of CFY, the data in this thesis is cited from the History of Yunnan Province.

paths, its relationship with the environment and landscape, and the social-economic benefits it brought for the whole CFY regions[11](Zhang, 2013).

From the viewpoint of technological influence, CFY was built to adapt to the changing landform and complicated river system in a mountainous area. Passing through three main rivers[12] in Southeast Asia, this route was technically marked with 155 tunnels and nearly 100 bridges wider than ten meters in Yunnan, 30 tunnels and 175 metal bridges in Vietnam[13], especially two spectacular bridges: Baizhai Bridge (le pont en dentelles) and the Namti Bridge (le pont sur arbalétriers) (Vassal, 1922). From the aspects of site survey, route planning, construction, railway management, stations, other architectural buildings, decorations and locomotives, all these technical indicators proved the engineering wisdom of the 19th century and the hardship of laborers from different countries in the railway company (CIY)[14]. Laborers and technicians paid a massive price for overcoming various difficulties, including topographic, climatic, and sanitary obstructions. As a result, nearly 60,000 - 120,000 workers and eighty engineers sacrificed in this event (Bordes, 2009)[15].

The ecological importance of this area is also unignorable. The entire region contains two international biodiversity hotspots, namely the Indo-Burma Hotspot[16] and the

[11] The areas passed by CFY as the study area will be defined in the next chapter.

[12] They are Nanpan River, Nanxi River and Red River. The part of CFY in Vietnam is parallel with the Red river.

[13] There were totally more than 3000 bridges and tunnels at the beginning, but most of them were destroyed and disappeared in the history.

[14] Compagnie française des chemins de fer de l'Indochine et du Yunnan (CIY) is the company in charge of the construction. But there were also various foreign contractors from both Italy and France during the construction process. The coolies were mainly Chinese and Vietnamese, and the technical workers are mainly from the Europe. And the constructor companies are from Italy, Greece, Belgium, India and France.

[15] The number of victims is still controversial in different studies.

[16] Recognized by the ICUN, this hotspot is one of the most biologically important regions on the Earth, providing ecosystem services for more than 300 million people living in this area.

Mountains of Southwest China Hotspot[17]. A combination of complex topography, river networks, climatic conditions, and historic changings results in extremely rich biodiversity, a large number of endemic species, various international protected areas, as well as a variety of coexisting cultures (Guo, et al., 1998; Chen, et al., 2013). Not as highway or road system with ecological disturbance, the historical CFY line coexist harmoniously with environment and becomes a part of regional landscape and an object of aesthetics for landscape enjoyment.

All these values mentioned above give this route a primarily historical and environmental significance, providing rich and diverse tourism attractiveness for visitors, as well as economic potentials for the regional development. There are more than one hundred sites of heritage related to this railway recorded, for instance, the well-known Bisezhai railway station, Haiphong station, Hanoi train street and Longbien bridge, which are all popular tourist destinations for visitors across the globe. A lot of valuable historical documents and images as a part of the railway heritage are still conserved in the museum and archives in both China and France[18], waiting for further studies, exhibitions and interpretations.

Evidently, from the perspective of history, culture and engineering, this railway is of great value and importance, and the whole railway area is also meaningful for ecological and landscape studies. This research on the railway heritage of CFY is not only a process for the documentation and evaluation of various kinds of railway heritage, discussion on the heritage protection and touristic reuse and services, but also caring about a combination of ecological system and social-cultural meaning for the future of the whole railway region. Furthermore, the necessity of this study is reflected by the problems and challenges which the old railway is meeting nowadays.

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[17] Recognized by the CI, it owns a cluster of distinctive flora and fauna.

[18] According to the fieldwork, the previous documents by the Indochina government were all transported to the Archives Nationales d'Orere-mer in France.

The specific study area of CFY needs to be defined, and the CFY line as a research object needs to be distinguished with other historical railways in Yunnan as well.

1.1.2 Current situation and challenges

CFY and the related regions are facing both challenges and opportunities because of all the economic and political changes in the past years. In the 20th century, after a series of wars, some of the sections had been damaged but repaired and reopened soon. Owing to the demands of capacity, stability, speed, and comfort of rail transport, the standard- gauge railway[19] began to spread in Yunnan since the 1970s. CFY totally lost its competitiveness and faced severe operating losses. Many of its stations were closed at that time. In 2003, the passenger service of CFY in Yunnan was suspended. In 2005, The Kunming-Hekou standard-gauge line as the part of the Trans-Asian Railway (TAR), started the construction and officially opened in 2014, whose route is basically parallel with the CFY line. Comparing with the TAR, the service of CFY is more time-consuming and in need of higher costs for maintenance. In particular, the one-meter railway cannot fit with other rail networks out of Yunnan province. Since then, those colonial stations along the CFY route became dilapidated, and this one-century-old railway cannot avoid a trend of decline (Zhang, 2010) (figure 2-3).

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[19] Namely the width of track gauge is 1,435 mm, firstly adopted by George Stephenson. Then, the Royal Commission on Railway Gauges in the UK defined it as the standard gauge. The track gauge of CFY is 1m, called the one-meter railway or narrow-gauge railway. There are also other non-standard gauge railways with various widths.

Figure 2, Abandoned station along the railway route

Figure 3, The rail was torn down in the center of Kunming (2017)

Despite of the insufficient awareness of railway heritage protection, railway enthusiasts and local governments have never stopped their efforts on saving this old railway and the related relics. Thanks to some groups of railfans[20], hiking along this route becomes an optional item in some local travel agencies. In recent years, the

[20] A person interested in rail transport. They have hobbies related to railway, such as photography, collecting railway models, studying railroad history and participating in events for the protection of railway station, locomotive, and other related relics.

Yunnan Railway Museum (figure 4) based on a previous railway station was reconstructed as one of the earliest railway museums in China[21], which has collected and systemized lots of related historical documents, publications, photographs, equipment, tickets, and various kinds of memorials of CFY. The Yunnan government also organized some site surveys along the route to record the current situation of the physical remains of CFY. In 2008, Kunming - Wangjiayin[22] section was firstly transformed into a tourist line for tourism and commuting. In 2010, the 100th anniversary of CFY attracted attentions from scholars, the public, even the descendants of former French workers. A few themed photographic exhibitions were successfully held in both Yunnan and France. Many historical images were displayed for the first time in front of the locals as a valuable evident of Yunnan's history.

Figure 4, Kunming railway museum

[21] Currently, there are in all 11 railway museums in China.

[22] There are in all 34.65 km of CFY developed into touristic lines, namely Kaiyuan - Data (11.65 km) and Kunming- Wangjiaying (23 km), accounting for 7.4% of the whole length of CFY in Yunnan. The section of Jianshui - Tuanshan and Kunming - Shizui are not counted, because they belong to the branches of CFY.

In order to solve the inefficiency of goods transport, the Kunming Railway Bureau (KRB) launched an international intermodal container in 2014 from the southern part of CFY in Yunnan to Vietnam (Mengzi - Haiphong). In 2015, the touristic train was open in Jianshui[23] (figure 5). For its great commercial success, other local governments also tried to learn from its experience and make better use of the heritage resources along CFY. In 2016, the *Planning for the Improvement of one-meter railway in Kunming* was officially released as a part of the Kunming Urban Planning, aiming to improve landscape quality and scenic experience for tourism along the CFY near Kunming. Afterward, a theme park was constructed in the most important station along CFY, namely the historical and cultural park of Yunnan-Vietnam Railway in Bisezhai[24].

Simultaneously, a commuter train was settled for the railway workers from Wangjiaying - Kaiyuan (Northern part of CFY), serving residents and workers from the nearby villages and towns. There are also several ongoing governmental projects, such as the Cultural Corridor based on the Namti Bridge by the government of Honghe, the Phoenix Ecological Park in Kaiyuan, the French style street in Kunming and so on. Fortunately, in 2018, in the first national list of Chinese industrial heritage, the whole railway of CFY was inscribed, which means a rising of consideration of railway protection within an overall and international perspective in Yunnan. In 2020, the Kunming government starts to interpret the history of CFY in local communities; a themed street was constructed in the center of Kunming to improve the cultural influence and public perception of railway heritage (figure 6). The Fosun International

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[23] A main station of the branch of CFY.

[24] The only special-class station in CFY, and an interchange station between CFY and its branch. It is now a popular tourism destination.

Conglomerate Company[25] shall also participate in the development plan of CFY, providing further reliable financial supports.

Figure 5, Touristic train in Jianshui

Figure 6, Posters of Yunnan railway history

In Vietnam, the colonial rail network is older than the section in Yunnan, which has been surviving for nearly 140 years. The narrow-gauge railway accounts for 84% of its whole national network, and the Vietnamese CFY has a percentage of 17% (VNRA, 2017). The CFY brought huge contributions to the national economy of Vietnam, which is still well-functioned for transporting passengers and freight as a part of the transportation skeleton to connect the north and south of Vietnam. The speed of one-meter train has been raised from 30 to 80 km/h, and sleeper compartments were installed for bringing comfortable traveling experiences. The section from Laocai to Hanoi was successfully transformed into a touristic train named "Orient Express Train"[26] (figure 7), attracting more and more international visitors and railfans. Besides, a public art project is done with the cooperation of Korean artists in the center of Hanoi, which decorated the arch walls along the Longbien Bridge, aimed to create a cultural and leisure space for local residents and visitors (figure 8).

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[25] "复星国际", a Chinese investment company based in Shanghai and Hongkong, started investing in Chinese railways since 2017.

[26] There are also other names of this line by the different traveling agencies in Vietnam.

Figure 7, Services on the Orient Express Train

Figure 8, Decorated wall with the theme of railway history in Hanoi

However, the railway system in Vietnam confronts similar problems with the situation of CFY in Yunnan, such as the low profitability, low velocity, high maintenance costs and poor quality of railway infrastructure, given the rise of highway, subway and airplane. The situation of railway heritage protection is worse than it in Yunnan. There remain only a few railway relics in Vietnam, like the French colonial stations conserved in Haiphong, Nhatrang, Dalat and Hue[27] (figure 9). And railway heritages in Vietnam did not get sufficient attention from the concerned academics. Only a British historian, Tim Doling, organized a website to interpret the Vietnam railway history and related railway remains to the public[28] (Doling, 2012). Other research result is still very limited.

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[27] Only the Haiphong railway station is related to the CFY, but other three stations belong to the South Vietnam.

[28] Website: http://www.historicvietnam.com

Figure 9, Colonial railway stations in Vietnam

Officially, the awareness of railway heritage protection has not been raised in Vietnam. In 2019, the government decided to close the famous Train Street in Hanoi (Figure 10) for some safety reasons, which used to be a popular Instagram site[29]. And the government is planning to update the historical railway system, replacing the old rolling stock fleet, locomotives, old railway stations, freight cars and passenger carriages, without considering their historical and architectural values. Though the railway protection of CFY in Vietnam is not as effective as the measures taken by Yunnan, Vietnam expressed its willingness to cooperate with Yunnan for the redevelopment of the whole railway heritage system (Nguyen, 2010). The French side

[29] A photo and video-sharing social networking service owned by Facebook Inc and firstly crated in 2010.

also revealed that international cooperation is badly needed for the application of a joint World Heritage site, which will bring tripartite wins for these three countries (Fan, 2013).

Figure 10, Train street and shops in the center of Hanoi

In conclusion, the situation of CFY in both Vietnam and Yunnan is not that optimistic. Though the Trans-Asian Railway and "The Belt and Road Initiative"[30] are strengthening further connections between China and Southeast Asia, the protection and management works are complicated, involving various shareholders and administrations. Some sections have already been replanned, some parts are redeveloped as touristic trains nowadays, but other sites are being neglected or destroyed; The commercialization and the protection of the authenticity of CFY need to be further discussed; The contradiction between the narrow-gauge railway system and urban construction is obvious in the metropolitan areas, and the public perception of railway heritage still needs to be raised and improved. Theoretically, the measures of railway protection need to be updated in accordance with the current trend of

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[30] A global strategy adopted by China in 2013, involving economic development and investments in nearly 70 countries.

heritage studies. The biggest challenge is the lack of comprehensive analysis, protection, cooperation and redevelopment system for a coordination of this large-scale heritage.

Throughout the recent experience of global cultural heritage protection, the idea of heritage protection has been evolved from the protection of single buildings to a heritage area and the integration of nature and culture landscapes. The concepts of "cultural route," "heritage corridor," and "big sites" became hot topics for large-scale heritage research; more modern technologies are introduced in the heritage protection in a larger extent from the perspective of site, landscape and environment, which makes is possible to integrate various cultural and natural resources, to coordinate the heritage investigation, assessment and protection by comprehensive methods and to improve the efficiency of heritage tourism and redevelopment.

Therefore, this research discussing the proposal of the heritage corridor system of CFY is imperative for both the Yunnan province and Vietnam. Based upon the complicated situation of CFY heritages, the author intends to display and interpret the distribution and classification of CFY heritages, to reveal and assess its ecological, economic, cultural, historical and touristic values as a heritage, update the system for assessing railway heritages and industrial landscape based on the heritage corridor system theory and the methodology of historical GIS. This system can serve for further academic uses and touristic supports to improve its national and global influences and the public perception of railway heritage, also providing new perspectives for other similar studies of the protection and development of railway heritages.

1.1.3 Define the study area

This study refers to three levels of different geographical extents, namely, the territorial background in a broad sense, the study area in a narrow sense, and the boundary of heritage corridor for heritage protection. The area located between Yunnan province in the southwest of China and North Vietnam[31](figure 11) is taken into consideration as territorial background for this research. Basic geographical conditions of Yunnan and North Vietnam, including climate, hydrology, soil, land cover, land relief and ecology, will be introduced in the next chapter.

In order to facilitate the research and delimit a specific study area, this thesis focuses on the administrative areas where the CFY is crossing: 102° 43' 12" E - 106° 42' 54" E, 20° 51' 53" N - 25° 03' 35" N, covering over an area of 51,414 km^2 in extent[32], including 13 counties in Yunnan[33]: Kunming City (Kunming, Yiliang, Chenggong), Yuxi City (Chengjiang and Huaning), and Honghe (Kaiyuan, Jianshui, Mengzi, Gebian, Pingbian, Mile and Hekou), as well as Maguan in Wenshan; Nine cities in North Vietnam include Laocai, Haiphong, Haiduong, Hungyen, Yenbai, Bacninh, Phutho, Hanoi and Vinhphuc, in all 22 administrative bodies[34] (figure 12). Furthermore, the boundary of heritage corridor will be defined in the third chapter while creating the heritage corridor.

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[31] The North Vietnam in this research does not refer to the independent country in the history, this term is used according to the division of geographical conditions in Vietnam as North, Central and South.

[32] Calculated in GIS by the administrative data collected from the https://www.diva-gis.org/gdata

[33] The administrative system in Yunnan is classified into three levels: city, county and countryside.

[34] For the different size of administrative divisions between China and Vietnam, the extension of a county is similar with the size of city in Vietnam, thus, the study area in Yunnan is shown by the division of county, but in Vietnam referring to the cities as a unit.

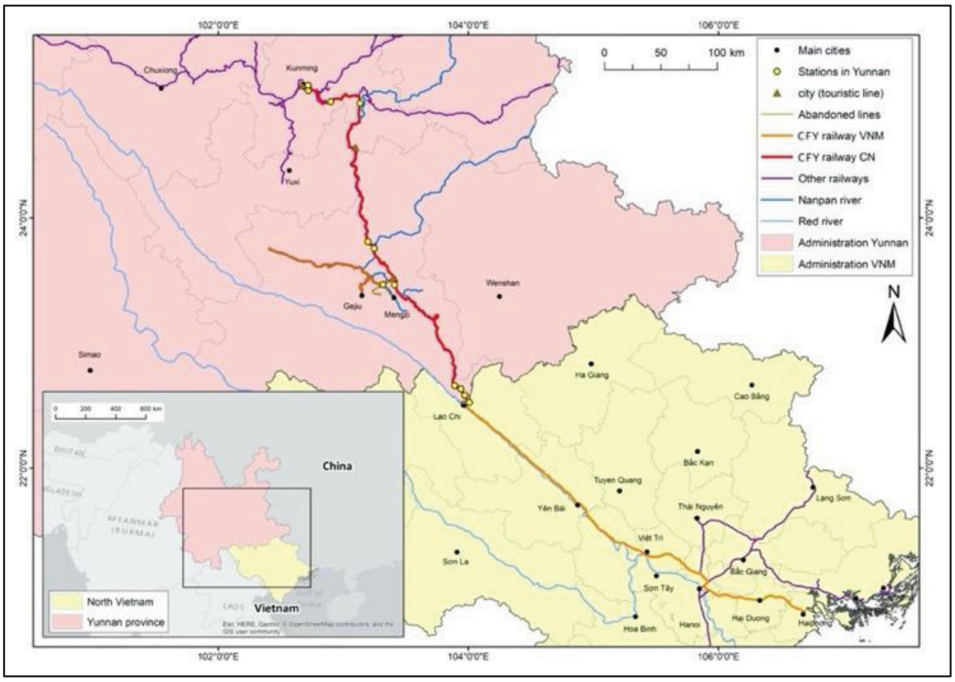

Figure 11, The territory of Yunnan and North Vietnam as geographical context

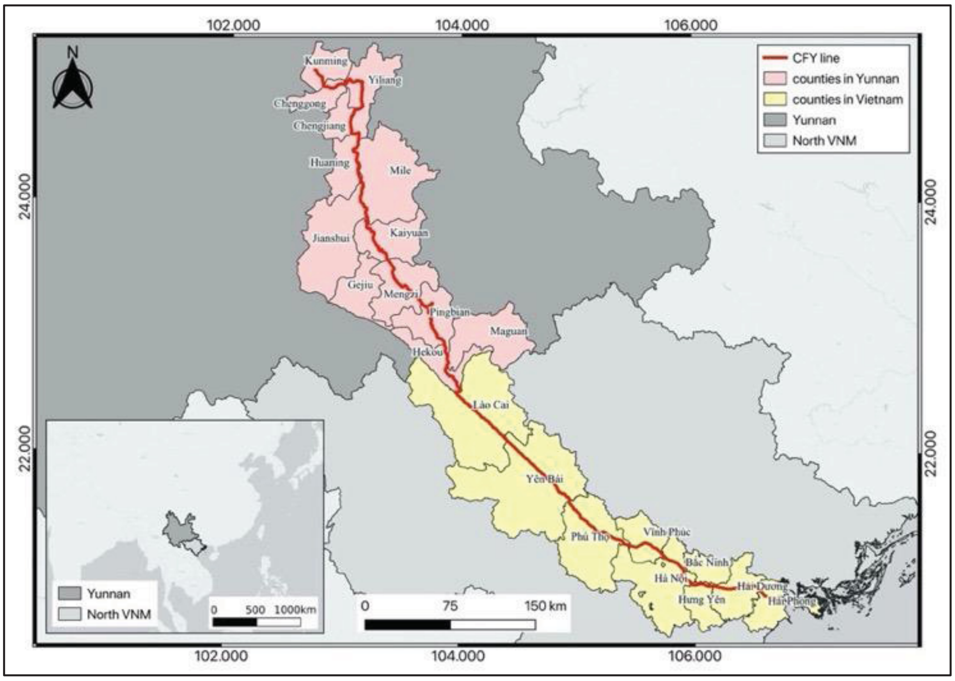

Figure 12, Study area and the administrative divisions

As for the time span of this study, CFY is a modern industrial heritage[35]. The history involved in this research started from the French invading in Vietnam and Yunnan in the 19th century, the establishment of the French Indochina colony, and the construction of the Yunnan-Vietnam railway as a background. The railway was finally completed and started to operate in the early 20th century. Later, it experienced many important historical events and periods. In contemporary, the railway facilities underwent destruction, demolition, reconstruction, abandonment, protection and redevelopment. But the historical range of CFY has never stopped and its story has been continuing to nowadays.

In addition, other railway systems in Yunnan and their relationship with CFY also need to be clarified. The term "Yunnan-Vietnam Railway" can be understood in a broad or a narrow sense. This thesis refers to its narrow meaning, namely the main body of the route from Kunming- Haiphong. Due to some historical reasons, broadly speaking, CFY also relates to the other two sections of railway systems in Yunnan, namely a part of the Yunnan-Burma Railway (YBR) and the Gebishi Railway (GBS)[36], which will not be involved as research objects in this thesis.

The construction plan of YBR was proposed by Britain, but it was suspended due to the World War II. Only a 12km-route was finished to connect Kunming with Shizui. Then, GBS is another narrow-gauge (600 mm) railway connecting with the mid of CFY by Caoba station. It was designated as a private railway funded by local industrial and commercial enterprises, which was totally constructed in 1936. With the rapid development of the industry of railway and highway, GBS was unable to meet the requirements of economic growth. In 2003, its passenger function was totally suspended. Nowadays, only a short section with four stops was redeveloped as a touristic line from Jianshui to Yuanshan, which is owned by a private tourism company- Jianshui Ancient Town Train Management Company. But all other parts of

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35 The Chinese modern history refers to the period from 1840 – 1949.

36 Gejiu- Bishezhai- Shiping (GBS), intersecting the CFY with the Caoba station.

the GBS were totally abandoned (figure 13). In daily life, people consider these two parts (YBR and GBS) as branches of CFY. But strictly speaking, these three railways need to be discriminated, especially in historical and geographical studies (Gao, 2013).

Figure 13, The abandoned section of GBS

Furthermore, according to the current operating and management situation, till June of 2020, the whole railway route of CFY can be classified into four sections with the five dividing stations (figure 14): North Kunming, Kaiyuan, Laocai (Hekou), Hanoi and Haiphong. The first section Kunming - Kaiyuan is totally stopped without any operating trains or freight services; The second section from Kaiyuan - Laocai (Hekou) is still functioning for transporting goods[37] to Vietnam even during the Coronavirus epidemic in 2020; The third section from Laocai - Hanoi is operated by the state-owned department Vietnam Railways (VNR) as the Oriental Express, and the passenger trains are conducted only during nights, which takes eight hours every turn for a travel of nearly 293 km; The fourth section from Hanoi - Haiphong also

[37] The goods mainly include iron ore, sulfur, fertilizer, coke, steel, etc.

functions for passenger and freight services but having the different schedules with the line to Laocai, which takes 2.5 hours for passing this section (99 km)[38].

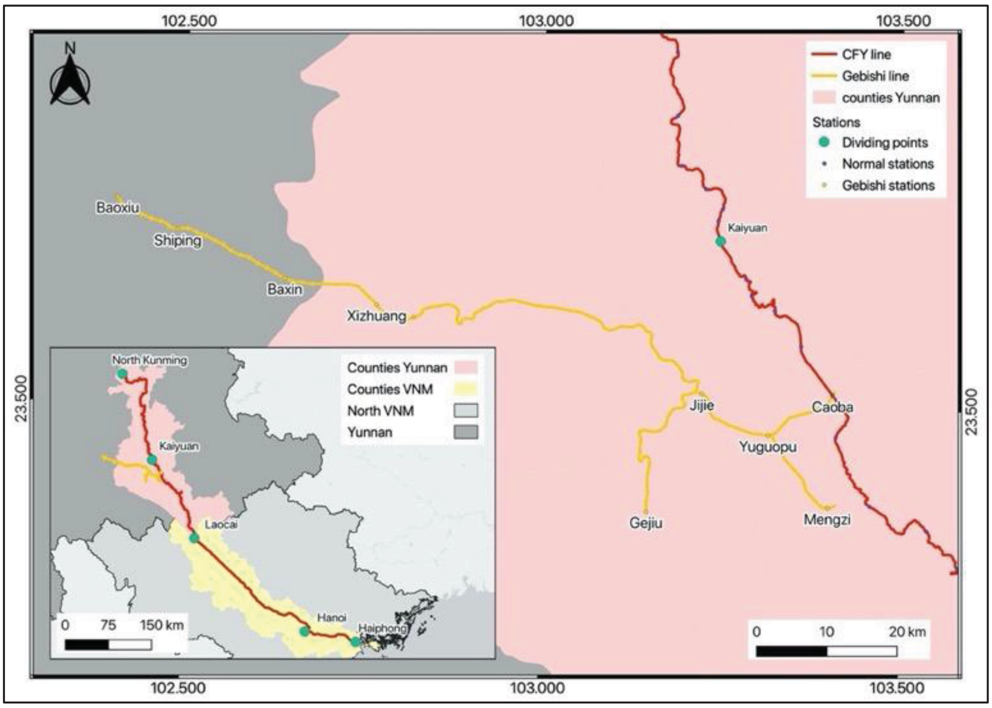

Figure 14, GBS connecting with CFY

[38] The CFY line in this research is obtained and digitalized based on the Open Street Map, then the length of every section is calculated in QGIS.

1.2 State of the art

In this subchapter, the most current research in the field of railway heritage is reviewed. It includes the emerging trends of international industrial archaeology, achievements of industrial heritage protection both at home and abroad, the studies of railway heritage, and Yunnan-Vietnam Railway from an international perspective, as well as an introduction of spatial technologies for the heritage protection. The reviews provide a critical survey of the literature in the past decades and the potential shortcomings of previous studies. Finally, it points out the possibility of combing the CFY studies with modern spatial technologies, and the meaning of Historical GIS in this research.

1.2.1 Development of industrial heritage

The early 20th century had witnessed a rise of interests in protecting industrial remains. After the Second World War (WWII), the urban renewal strategies at that time posed some threats to those old but meaningful buildings and factories (Jacobs, 1961). In the same period, Michael Rix firstly described the term "Industrial Archaeology (IA)" during the surveying, recording, conserving and interpreting of the monuments left from the Industrial Revolution (Rix, 1955; Rix, 1967). Though the origin of this term is still in dispute, the survey by Rix did protect the memories and symbols of industrial age from disappearing and destructing (Hudson, 1963; Orange, 2008). Under some criticism (Foley, 1968), more scholars and studies followed the route of Rix and continued to discuss the definition, fields, scopes and approaches of IA study (Buchanan, 1974; Palmer, 1990).

In 1959, the Council for British Archaeology held the first national IA conference, given rise to the IA research in the UK. Meanwhile, in the USA, there were also some early practices and research dealing with the protection of industrial remains. For example, the Greenfield Village and Henry Ford Museum had collected former machines and artifacts relating to the American industrial history. The age of the 1950s, thereby, is regarded as a beginning of international industrial heritage studies (Que, 2007).

Sequentially, Kenneth Hudson[39] tried to raise social awareness of industrial heritages perception and successfully introduced the academic achievements in the UK to the USA. Besides, the demolition of Doric portico at Euston Station stimulated national debates on the protection of industrial remains in the UK (Orange, 2008), which also influenced global IA research in the 1970-1980s, brought more concerns on the relationship between urban revitalization and IA protection. More types of industrial

[39] A British journalist and book author (1916-1999).

sites such as ironworks, textile mills and historical transportation facilities were started to be involved in the IA studies (Nevell, 2006).

Many associations of IA were constituted during this period, such as the Society for Industrial Archeology (1971) in the USA, the association for Industrial Archaeology (1973) in the UK, and the Comité d'information et de liaison pour l'archéologie (1978) in France. The First International Conference on the Conservation of Industrial Monuments was organized in 1973 at Ironbridge in the UK, leading to further international academic exchanges. The constitution of "The International Committee for the Conservation of the Industrial Heritage" (TICCIH) in 1978 was considered as a symbol of international cooperation of industrial heritage protections. Since then, the word "Industrial heritage (IH)" has been widely accepted and the activities for IH protection developed rapidly, especially in the industrialized and developed countries (Falconer, 2006).

A series of guiding principles were carried out, including *Venice Charter* in 1964, the *Charter of Machu Picchu* in 1977, *Granada Convention* in 1985, *Washington Charter* in 1987, *Nara Declaration* in 1994, *Dublin Principles* in 2011, *Taipei Declaration* in 2012, and *Turin Charter* in 2018, forming the common criteria for industrial heritage studies and the international protective practices[40] (Minchinton, 1983).

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[40] Full name: The Venice Charter for the Conservation and Restoration of Monuments and Sites.
The Charter of Machu Picchu.
The Convention for the protection of the architectural heritage of Europe.
Charters for The Conservation of Historic Towns and Urban Areas, Washington Charter.
The Nara Document on Authenticity.
TICCIH Principles for the Conservation of Industrial Heritage Sites, Structures, Areas and Landscapes.
Taipei Declaration for Asian Industrial Heritage.
Turin Charter by Fédération Internationale des Véhicules Anciens.
The Nizhny Tagil Charter for the Industrial Heritage.

IA stepped into a mature stage from the 1990s, seeing early inscriptions of industrial heritage in the World Heritage List, like the Ironbridge Gorge in Britain, the Völklingen Ironworks in German and the Major Mining Sites of Wallonia in Belgium (Buchanan, 2005; Que, 2007). Industrial sites were started to be interpreted as a harmonious part of landscape and environment (Hoefer & Vicenzotti, 2013). What's more important, the *Nizhny Tagil Charter* officially clarified the definition, value and importance of the identification and conservation of industrial heritage, which is considered as an authoritative guide for worldwide IH protection (TICCIH, 2003). And the *Xi'an Declaration,* published in China in 2005, further confirmed the meaning of protecting industrial landscape in a broader context rather than isolated monuments of IH. The international influence of TICCIH has further expanded, with an increasing number of research and projects emerged, contributed to the development within the field of IA.

As a result of the development for nearly fifty years[41], 28 IH sites were acknowledged by the UNESCO at the beginning of the 21st century. But most of them (79%) locate in Europe and North America (Falser, 2001). This number was increased to 71 based on the World Heritage list[42] in 2018, showing that most of the IH sites belong to the sectors of mining and quarrying (34%), manufacturing (21%) and transportation industry (20%) (figure 15). However, the worldwide distribution of IH is still very imbalanced, revealing a reliable comparison between the number of IH in Europe (48 sites) and in Asia (5 sites)[43]. It implies that the protective strategies and overall heritage identification need to be implemented immediately, especially in the

[41] From 1955 – 2000.

[42] Website: https://whc.unesco.org/en/list/stat/ (searching time: 01/02/2018). It is counted by the author on the bias of the definition of industrial heritage by TICCIH.

[43] China and India each owns one site, and Japan has three sites.

developing countries, such as in China and Vietnam, where there is only one IH site accepted by the UNESCO[44].

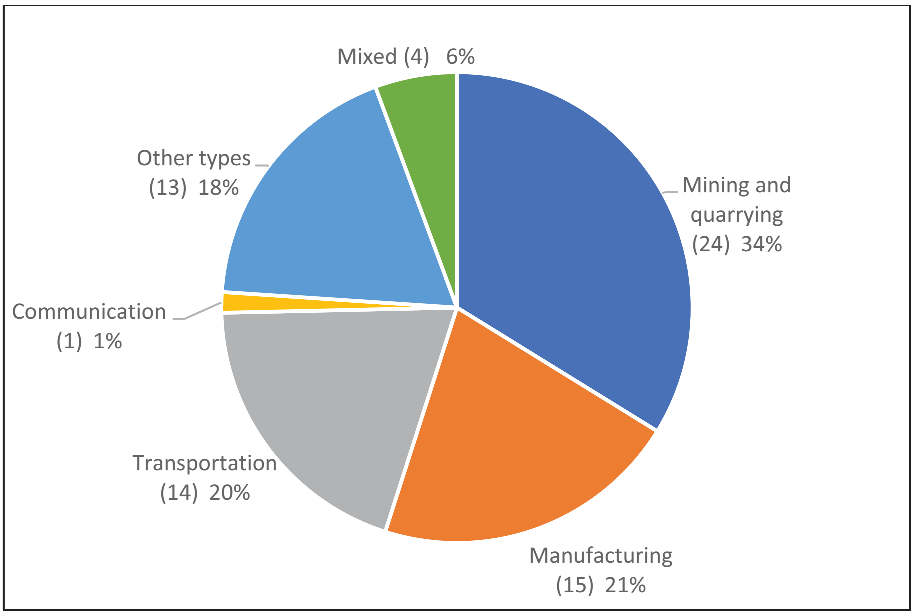

Figure 15, Type of industrial heritage in the UNESCO list

Looking into the situation in China, IH studies were started from the late of 20th century in the architectural reuse of old industrial factories. LU firstly discussed the aim and model for the redevelopment and redesign of port industrial districts, seeing them as heritages for exhibiting the industrial history (Lu, 1999). LI introduced the experience of tourism development and landscape modifications in the Ruhr area in Germany (Li, 2002). HE introduced the history of IA studies in Europe and the USA, as well as the pattern and principals of industrial landscape design, regarding industrial heritage as a part of industrial landscape for a comprehensive protection instead of protecting individual buildings or structures (He, 2004). Notably, the

[44] Dujiangyan irrigation system in Sichuan province, a historical irrigation system originally constructed around 256 BC and inscribed by UNESCO in 2000.
The UNESCO heritage sites in Vietnam are mainly natural landscape and ancient architectural relics.

famous site transformation of Beijing's old industrial sites - 798 art district in 2002 became one of the common concerns for the whole society in China.

More importantly, the publication of *Wuxi Suggestions*[45] in 2006 and *Notice of the Strengthening the Protection of Industrial Heritage* by the Chinese government can be seen as a turning point of Chinese industrial heritage study, which clarified and conformed the urgent situation of Chinese industrial heritages. Yu and Fang systematically translated the definition of industrial heritage in line with the *Nizhny Tagil Charter*, listing the potential heritages according to Chinese modern industrial history (Yu & Fang, 2006). In 2008, during the Third National Survey of Cultural Heritage, it was recognized that industrial heritage could be classified as an independent category of cultural heritage for the first time in China. Since then, more scholars started to conduct regional surveys and research for rescuing the relics of the traditional industrial towns and sites in danger (Que, 2008).

Into the 21st century, the research of industrial heritage in China gradually involves more directions and disciplines: recording and assessing of IH, building industrial database, adaptive reuse, urban renewal, industrial tourism, brownfield planning[46], industrial landscape, industrial culture, policy and law, geo-design strategy and so forth (Liu & Li, 2010; Liu, 2012). Later, the *Taipei Declaration* was published by TICCIH, emphasized the different situation of industrial heritage between Asia and the West, the importance of further research and protection in Asian countries according to their own historical and cultural backgrounds, the meaning of local identity for the original residents living around, as well as the necessity of

[45] The first official charter of IH in China proposed by the by the Chinese National Cultural Heritage Administration, seeing a new stage for the protection, management and research for Chinese industrial heritage.

[46] "A brownfield is a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" defined by the Environmental Protection Agency (EPA) In USA.

international cooperation to promote the preservation of Asian industrial heritage. In 2014, the Asian Route of Industrial Heritage (ARIH) was founded. In 2018, the first list of National Industrial Heritage (table 1) was finally brought out as a fruit of nationwide efforts. Continuously, in 2019, the Association of Urban Planning in China published the second list of National Industrial Heritage[47], in which 100 sites of industrial sites and factories are involved, as well as several lines of old railways.

Table 1, Inscribed sites in the first Chinese National List of Industrial Heritage (2018)

In 2019, the national industrial heritage convention was held in Zhengzhou, discussed the memory of Chinese industrial history, the development of Chinese urban construction, and the evaluation and composition of Chinese industrial heritage, etc. It was also proposed to display the historical features of China's industry from more perspectives by means of protecting historical images, real objects of relic, and the oral history of an area. And three directions of Chinese IH studies were pointed out in need of more concerns: public perception to the industrial heritage; scientific decision-making of urban planning and IH protection; and the inheritance of industrial culture.

According to the statistic of IH sites in the lists of the Chinese Major Historical and Cultural Site, IH sites account for only 2.5% of all the Chinese cultural heritage sites[48]. Most of the IH sites are located in the Northeast and Southeast of China, in accordance with Chinese early industrial development. As for the classification of Chinese IH, the military industry accounts for the most with a percentage of 25.5%,

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[47] Website: http://www.planning.org.cn/news/uploads/2019/04/5cb0447996966_1555055737.pdf (In Chinese)

[48] 110 sites are involved by the author from the eight lists of the Major Historical and Cultural Site published in China from 1961-2019. This statistic is made in 01/20/2019 by the author. And no data is shown in Taiwan, Hongkong and Macao.

then the road and railway 19.1%, manufacture 14.5%, and bridge 10.9% (figure 16), which means that the military and transportation industries are the main sources (55.5%) for Chinese IH sites, representing the characteristic of Chinese modern industrial history.

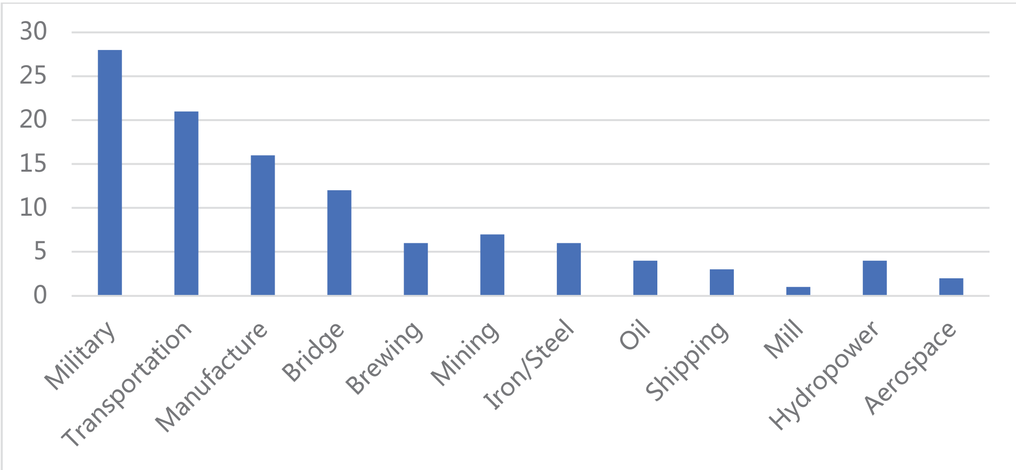

Figure 16, Classification of the industrial heritage in China

However, the complete theoretical system of IH has not been formed in China, and the related standards/ regulations for the heritage survey, identification and evaluation of industrial heritage have not been unified and legislated. On a national scale, research on the construction of industrial heritage information database and system is in need to guide the IH protective practices. The establishment of a national database will lay a foundation for the national IH survey. And building the Chinese industrial heritage data platform will also serve for further heritage management, monitoring and improvement of the evaluation system of Chinese industrial heritage.

On a regional scale, most of the practical explorations and transformation of industrial sites are driven by economic forces, with limited public participation and perception. Throughout the academic results of industrial heritage, Chinese industrial heritages are mainly distributed in economically developed areas, and mostly concentrated in the regions with earlier industrial accumulation in the history, where it also received more academic attentions than other regions, like Beijing, Tianjin and Shanghai. However, in other small cities or towns, industrial heritage is still neglected and facing more dangers and problems, such as the southwest inland of China. Further research should focus on the characteristic of local industrialization, taking more types of industrial heritages from different ages and regions into consideration.

In Vietnam, its early industrialization process was closely related to the French Indochina colony. Generally speaking, the Western modernization and colonization started the early industrialization in Vietnam. But the "Industrialization of Indochina" was limited to the demands of French production. Under the control of capitalism, the economic structure in Indochina was centered on the export of raw materials and natural resources. In the colonial development after World War I, the sectors of light industry (tobacco, wood, brewery and textile factories), mining industry and transportation were mainly invested and developed by French capital. In 1930, the areas of mine exploration reached to one-fourth of the whole territory of Indochina, where it had become an important export destination and producer of metal minerals in the Far East. In order to facilitate the colonial economy and political ruling, France had strengthened the construction of the transportation industry since the beginning of the 20th century. Reginal networks of railway, roads and seaports had been built within the Federation of Indochina. The length of the railway was 2,569 km till 1939, including the part of CFY in North Vietnam (Liang, 1999).

After the independence of Vietnam in 1945, due to the North-South Division (capitalism and socialism), Vietnam's social modernization was deformed, and years of violent conflicts (Vietnam War, Sino-Vietnam War etc.) had led to economic decline and chaos, which also missed the opportunities during the third wave of industrialization. Till 1986, economy has gradually become the focus of government works, and the Market-oriented system reform was started, which successful brought the industrial development in energy, machine, chemical industry and urban constructions.

Because of this special historical background, the society of Vietnam is still in a rapid process of industrialization, the modern industrial heritages did not get enough concerns in academia. And Vietnam has not participated in the association of Asian Network of Industrial Heritage. The CFY is an example, compared with Yunnan province, who is positively protecting and redeveloping the railway heritages, the railway remains along CFY in Vietnam have already been updated with new forms and techniques. Also, during the contemporary urban planning, the local governments hope to obtain a higher level of urban classification from the examples of Ho Chi Minh City and Hanoi, meanwhile, the value of agricultural fields, traditional villages and modern heritages are always ignored (Henein, et al., 2019). Among all the modern remains in the Vietnamese history, “wartime heritage” and “colonial architectural buildings” are hot issue in Vietnam. Especially in the tourism industry, the Vietnam-American war was defined as a principal orientation and area of tourist activities as a method for reconstruction and economic development. There are also some discussions focused on the touristic development of those war relics and colonial buildings (Tang, et al., 2017), as well as the construction of army museums, protection of bombed sites, tunnels, graves, old prisons and military areas, which are served for political propaganda as a national spirit and will for independence and peace (Henderson, 2000). Other kinds of industrial remains and local cultural identities are still in need of further concerns and studies during its urbanization process.

1.2.2 Railway heritage protection

Rail was initially designed for conveying minerals more efficiently in mining areas in the past. The material of rail itself was developed from wood, cast iron to iron and steel. In the early 19th century, the introduction of steam locomotive traction and the invention of tubular boiler successfully redefined the function of railways. As the first successful steam locomotive invented by George Stephenson[49] and adopted in the Stockton-Darlington railway in 1825 in England, railway system started to spread to Europe, America and further into their colonies, regarded as one of the most important technological inventions in the 19th century. From the 1900s, the diesel-powered locomotives started to replace steam engines. In the 1960s, high-speed railway emerged and brought more breakthroughs for the railway industry.

As a symbol of modernity and a carrier of industrial-technological achievements in history, railway facilitates the connection of spaces and endows them with more social and political meaning. The update of railway network and railway technologies caused some direct or indirect impacts on the territory's appearance and ecological process. It also strengthened inter-regional exchanges and improved the way of leisure in our daily life (Romanova, et al., 2015). While in some periods, airplane and car gained more market share in the tourism industry, redeveloping historic rails as tourism attractions can be a strategy to bring back economic outcomes, to compete with other means of transport, to meet the nostalgia for steam age, and enhancing the local cultural identity (Dann, 1994; Prideaux, 1999).

Later, the historical and scientific significance of railway had gradually been realized along with other kinds of transport heritages (Li, et al., 2015). The activities of railway heritage protection raised in the 1960s in Australia and the UK. Railway was successfully acknowledged as one independent category by ICOMOS (Coulls, 1999), and five heritage railways are officially recorded in the World Heritage List, which includes the Semmering Railway in Austria, the Rhaetian Railway between Switzerland and Italy, Mountain Railways of India (table 2)[50]. Lee (2000) listed other potential railway heritages in Asia for the UNESCO, and CFY is also included in this list.

Table 2, Comparison among railway heritage in the World heritage list

Semmering was considered as the first mountain railway in Europe. Constructed in 1848-1854, it was designed by the engineer Karl Ritter von Ghega[51], connnecting Gloggnitz to Murzzuschlag (Austria) in the Alps area. Its creative works proved the technological value as a railway heritage, such as the 17 curved viaducts built by bricks and stones no mechanical assistance, some of them are with a “double deck structure”. In 1952, double-track railway was implemented, and the transportation capacity was increased significantly. But the tunnels and bridges along the railway were well protected. After nearly 170 years of development, this railway has been evolved from a small locomotive train at the beginning of the railway civilization to the Intercity train with a speed of 160 km/h. Under the maintenance of the Austrian National Railway, it has become an excellent example of the balance between preservation of railway monuments and modernization. In 1998, it was successfully inscribed as the world's first railway heritage site. According to UNESCO, this railway system should be conserved from a landscape perspective, whose buffer zones are classified into core zone of railway facilities, local surrounding, historical landscape for settlement and tourism, supplementary area for tourism and supplementary settlement area (figure 17).

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49 1781-1848, a British mechanical engineer, known as the "Father of Railways".

50 “Mountain Railways of India” includes three lines: the Darjeeling Himalayan Railway, Kalka Shimla Railway and Nilgiri Mountain Railway.

51 An Austrian nobleman (1802-1860), he also worked as engineer and architect.

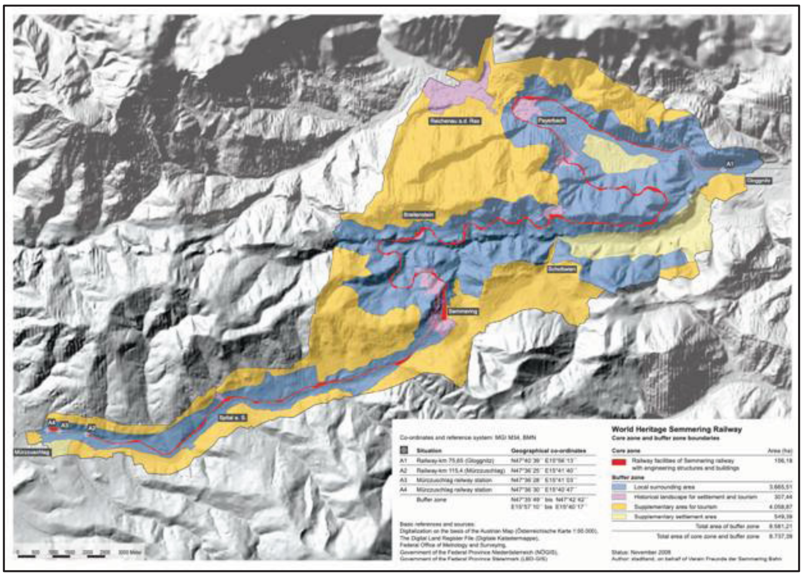

Figure 17, Buffer zone of Semmering

The Darjeeling Himalayan Railway (DHR) in India is another outstanding railway work from the aspects of social, economic, and political meanings and landscape quality. Extending from New Jalpaiguri, Siliguri to Darjeeling, this route was aimed for transporting tea for the English company. Located also in the mountainous area of Himalaya. The inspiration of design for the line came from the Festiniog Railway in Wales. The engineering works avoided the expense of grand structures. Thus, loops or double loop (climbing in a form of circle) and zigzags are common during the route to adapt to steep grades and effective expedients. Despite of its limited distance, the DHR was recognized as a remarkable railway, which is well preserved till today as a famous touristic line, especially for its harmonious relationship with the landscape. The diversified scenes include tropical plains, lowland jungle, Himalayan pines, as well as the perennially snow-covered mountains, which provides a high-quality landscape enjoyment. Thus, it was registered as a World Heritage site in 1999, also as the first official heritage railway in Asia.

Between Switzerland and Italy, the Albula and Bernina railways are joint as a heritage site as the “Rhaetian Railway in the Albula / Bernina Landscapes” in UNESCO. The Albula section has a length of 67 km, impressed by its 42 tunnels and 144 viaducts and bridges. The Bernina part (61 km) owns 13 tunnels and 52 viaducts and bridges. It is described as "a property with exemplary of the use of the railway to overcome the isolation of settlements in Alps in the early 20th century, with a major socio-economic impact on life in the mountains. It constitutes an outstanding technical, architectural and environmental ensemble and embodies architectural and civil engineering achievements, in harmony with the environment" (UNESCO, 2008). The official document classifies its buffer zone into core zone, primary buffer zone, buffer zone in the "near" area and buffer zone in the "distant" area (figure 18).

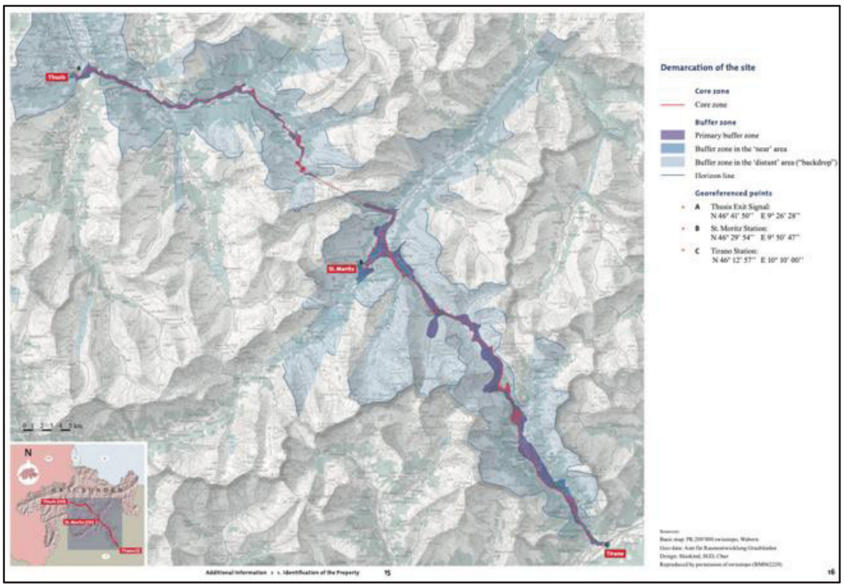

Figure 18, Buffer zone of Rhaetian Railway

As is seen, the protective strategies of railway heritage can be summarized into two categories, namely depending on the extent of the railway sites. The single railway stations or bridges are usually redeveloped reused with new functions. And for the whole railway line with outstanding meanings, they can be regarded as a linear landscape heritage, such as the UNESCO heritage sites mentioned above. The reuse of the historical stations follows the guideline of architectural heritage, and there are abundant practical cases of the station renewal. For example, the Manchester museum of science and technology was built based on the Liverpool railway station; the St Pancras railway station retained its basic architectural shape and function, served as a new railway station; and the Musée d'Orsay in Paris was remained from the Orsay railway station (Han, 2016). Theoretically, series of studies discussed the protection of the single railway stations (Zhu, 2012; Zhang, 2015; Lee, 2015; Bottero, et al., 2016; Yi, 2017). During the convention of industrial heritage in Italy (Stati Generali del Patrimonio Industriale 2018), the section of railway heritage discussed its reuse and development. The importance of railway enthusiasts and touristic train in the heritage tourism are emphasized (Fontana, 2020). The concepts of linear heritage, cultural route and heritage corridors are the main theories for the large-scale railway heritages. And these main concepts will be introduced in the next subchapter of theoretical context.

1.2.3 Railway heritage in China

In Asia, the development of railway history is relevant to the colonial activities of western counties, such as the French colonists in Vietnam, the British forces in Japan and multiple foreign influences in China. Railway construction was part of the spreading of new imperialism in the late 19th century. The first railway in China was the Wusong Railway constructed in 1876 in Shanghai by the British. However, for the misunderstanding from the public, this railway was totally demolished after just one year of operating. Then, the Qing government started the Westernization Movement[52], aimed at studying science and technology from the western countries. Among all the measures, the construction of railway was considered with a particular importance. Then, China's second railway was a standard gauge railway proposed by the Qing government, namely the Tianjin (Tientsin) Railway in Hebei. It had a length of 9.2 km, constructed for the transportation of coals in mining areas in the North of China.

In the late 19th century, Britain, France, Russia and other countries expanded their invasion in China, thereby obtained various benefits and rights in China through unequal treaties, which included the right of building of railways. In 1898 Germany was allowed to build the Jiaoji Railway in Shandong. Russia obtained the right to build the Chinese Eastern Railway (CER) in Northeast China. France successfully built the CFY to link French Indochina with China. Although China was almost becoming a semi-colonial country, the Chinese railway industry during that period had significantly been accelerated thanks to those early colonial railways.

With the national crisis, there was a rise in the domestic demands for defending the rights of constructing roads and railways. The Qing government decided to build a

[52] Qing is last imperial dynasty of China from 1644 to 1911. And the movement was from 1861-1895.

self-designed railway in Beijing. The chief engineer, Zhan Tianyou[53], creatively proposed the "herringbone" structure and completed the project in a mountainous area. This is the first self-designed railway in China, connecting Beijing with Zhangjiakou city in Hebei province. In 1909, it was officially operated, covering a length of 201.2 km.

Since 1949, more than 23,500 km of railways have been built independently in the mainland of China, but nearly half of them were damaged during wars. In the early 1950s, China decided to improve the railway system in the western regions. From 1953, the railway construction in China had continued to expand, and the Guikun Railway, Chengkun Railway, Xiangyu Railway and Taijiao Railway were successfully developed in the southwest and northwest regions. In the central and eastern regions, the Jingtong Railway, Jingcheng Railway, Wangan Railway enhanced the transportation capacity in China. At the same time, some masterpieces of railway bridge have been completed over the Yangtze River and Yellow River, thereby, formed the backbone of the Chinese railway network. For political and economic reasons, modern Chinese railways were located unproportionally in different regions (figure 19). But all these constructions left potential railway heritages in China, containing not only colonial and mining railways, but also various types such as mountain railways, forest railways, urban tramways and so on (Zhu, 2009).

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[53] (1861-1919), for his successful leadership during the railway construction, he was known as the "Father of Railway" in China.

Figure 19, The Chinese railway system

In 1980, the Chinese Ministry of Railway officially issued the *Notice on Strengthening the Management of Historical Physical Objects and Materials of Railways*, which was considered as the beginning of the protection of railway memorials[54], and the railway museums in China played the central role in collecting, systemizing and protecting railway remains. However, due to the rapid renewal of railway facilities in China, nearly 10,000 kilometers of non-standard railways were demolished at that time. Nearly 90% of railway stations were relocated or abandoned. In addition, because the railway facilities cover a large portion of land near the city center, which conflicted with the urban constructions, the local governments often ignored the values of railway heritages in pursuit of short-term economic benefits (Yang, 2011). The destruction of Tsinan Railway Station, stations of Yunnan-Vietnam

[54] Small pieces of railway relics, such as the signal light, train tickets, surveying and construction facilities, etc

Railway, and other historical urban trams in Tianjin, Shanghai, and Shenyang are the examples and reminders for the whole society (Xu & Yan, 2018).

At present, there are only a few railway heritages that have attracted the attention of scholars and the public in China: mainly those railway stations and bridges with unique artistic and architectural values; the operating railway and auxiliary facilities with a long history; and those in good conditions to restore for the touristic uses. In the Chinese National Industrial Heritage List, there contain nine railway bridges[55] and seven railways: Tangxu Railway, Chinese Eastern Railway (CER), Yunnan-Vietnam Railway, Jiaoji railway, Jingzhang Railway, Baocheng Railway and Bashi railway (figure 20)[56]. A comparison of characters of these seven railways is made from the aspects of academic attention, year of construction, location, railway-gauge, length, constructor and their academic attentions on the CNKI (table 2-3).

Table 3, Comparison of academic attention among five railway heritages in China

Table 4, Information on seven railway heritages in China

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[55] They are Nanjing Shimonoseki Train Ferry, Luohe Iron Bridge, Zhengzhou Yellow River Railway Bridge, Tianjin Jintang Bridge, Shanghai Waibaidu Bridge, Jinan Luokou Yellow River Railway Bridge, Qiantang River Bridge, Wuhan Yangtze River Bridge and Nanjing Yangtze River Bridge.

[56] Tangxu Railway: Tangshan-Xugezhuang, Chinese Eastern Railway: Harbin - Manchuria, Yunnan-Vietnam Railway: Kunming-Haiphong, Jiaoji railway: Jiaozhou-Jinan, Jingzhang Railway: Beijing-Zhangjiakou, Baocheng Railway: Baoji-Chengdu, Bashi railway: Shixi-Huangcunjing.

Figure 20, Seven railway heritages in China

However, the results of theoretical studies on railway heritage in China are minimal. Dong & Hou (2012) firstly introduced the experience of railway heritage protection in Europe to China. Zhang studied the railway heritages in the World Heritage List, made a comparison and discussion of the UNESCO criteria for the selection of railway heritage (Zhang, 2012). Tang defined the concept of railway heritage and the recognition of its values in China (Tang, 2016). Han introduced the railway history in the UK and their protective solutions for railway heritage (Han, 2016). Besides, many cases are studied focusing on various railway sites, discussing their heritage situation and touristic redevelopment, such as Tibet railway (Li, 2008), CFY and CER, etc. There are also other research perspectives from the environmental impact of railways (Yang, 2012) and landscape quality along the railway heritage (Zhang, et al., 2014; Zhang, 2015).

Under the topic of “Railway Heritage”, there are totally 119 academic articles collected in CNKI. CER is the one mentioned and studied most frequently among all the railway heritages, accounting for 42.0% of all the publications, and the second place is the CFY (14.3%) (figure 21). After analyzing the 119 articles on CNKI, it is found that the railway heritage study is interdisciplinary, involving archaeology, geography, urban and landscape design and information technologies. 48.3% of the articles focus on the protective and design strategies of the historical railways, then the discussion of the concept, value and elements of railway heritage (21.6%). But the current research method is mainly qualitative and comparative. Various research approaches, especially the quantitative methods need to be introduced, and the advanced spatial technologies which have been improved as helpful and effective for archaeologies, can also be introduced for the railway heritage studies.

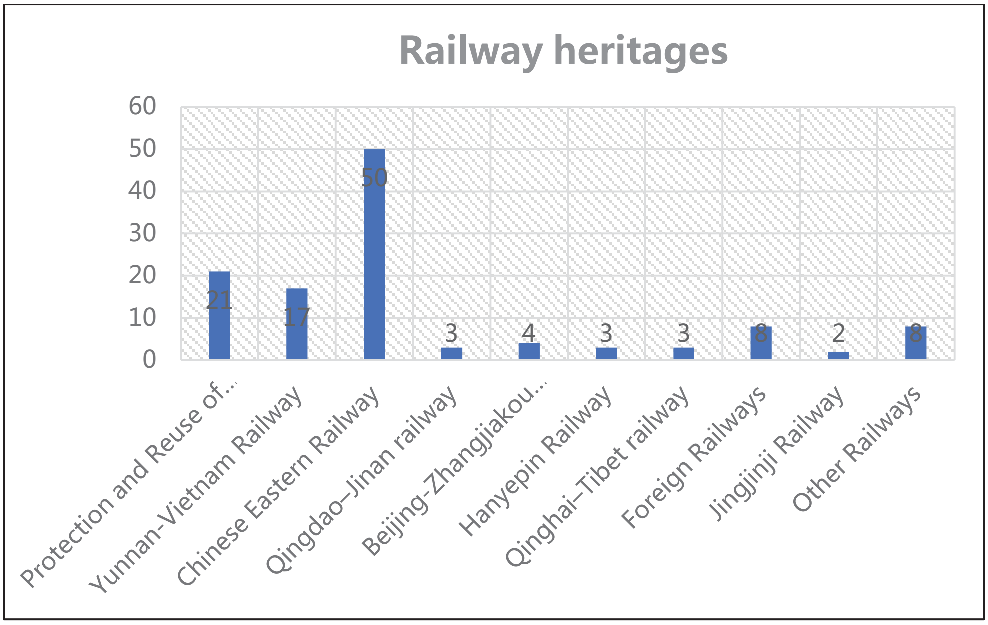

Figure 21, Topic of railway heritage studies in CNKI

Besides, in the process of protection and reuse of railway heritage in China, tangible heritages (bridges and stations) are always in a central position for scholars, for example in the national list of industrial heritage, there are more registration of railway bridges (Zhuhai bridge, Tianjin bridge, Zhongshan bridge, etc.). As for CFY, more publications in the database of CNKI are involved in the study of architectural value of railway stations such as in Jilin (Wang, 2010), Shanxi (Zhu, 2012) and Nanjing (Hao & Zhou, 2016). Still, other types, especially the intangible heritage such as railway technologies and movable railway memories recorded by photos and maps have always been ignored. In fact, photographic technology has brought contributions to many academic fields, as a scientific medium helping in the systematic documentation of ethnographic phenomenon (Harper, 1988); describing the picturesque landscapes and nature in accordance with esthetic practices; influencing its readers in form of mass communication; attracting curious visitors to the new territories recorded by those pioneer explorers (Karin, 2015). The term "Historiophoty" was put forward, which mainly utilized visual images and films to interpret the history and our thoughts about the past (White, 1988). When the modern visual media were started to be presented in front of the public, images as not only a supplement to traditional manuscripts, but also a special approach have been valued in historical studies.

Thus, railway heritage cannot be simply reused as just economic and touristic resources. The connection between its social values and the local identity needs to be strengthened. The local/railway culture and lifestyle should also be respected, at the same time addressing the economic goals of regional development, reusing and protecting the heritage resources in a larger context of landscape and environment where the railway heritages pass through. And the meaning of railway heritage should also be rethought, to embrace a comprehensive heritage system.

1.2.4 Review on the Yunnan-Vietnam Railway

The results of recent research on Yunnan-Vietnam Railway are quite abundant with a various spectrum of topics. Most publications, including books, proceedings, academic articles and photographic works, are in Chinese mainly from viewpoints of its historical (Wang, 2012; Feng, 2017; Zhuang & Fan, 2018) and cultural influences (Wang, 2005; Wang, 2007; Zhao, 2011). But foreign research about Yunnan-Vietnam Railway is really limited. Till now, the Vietnamese section of CFY has not been studied and there are no research records found in Vietnamese[57]. A small number of articles are published in French (E.g., Park-Barjot, 2008; Cam, 2014). And in English literature, there are some studies relating to the historical constructions in French Indochina (Goscha, 2009; Gunn, 2011; Goscha, 2012). However, lots of original documents in French are still conserved in the French archives, which have been seldom studied by Chinese or other international scholars. An international study on CFY is needed to integrate the Chinese records with the French documents. The collection and classification of the original French documents will be discussed in the following chapter of methodology.

In order to figure out the current situation of Chinese research on CFY, some complementary searches were done focused on relevant academic articles published up to 2018. The scientific databases CNKI is used for searching the keyword "Yunnan-Vietnam Railway (in Chinese 滇越铁路)". As a result, there are 411 published journal articles involved (search time 15/01/2018). Then the most relevant 174 articles are selected for a qualitative analysis by the visualization tool in CNKI. The analysis result is as follows:

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[57] Searched by the keywords "railway heritage, historic railway, and Laocai - Haiphong railway" in Google scholar (in Vietnamese "Di sản đường sắt, đường sắt lịch sử, Tuyến đường sắt Lào Cai - Hải Phòng").

Shown in figures 22, the research of CFY started early in the 1930s (the period of Republic of China), the publications increased irregularly from 1985-2005, showing a growing trend especially since the publication of *Wuxi Suggestion* in 2005, and reached to a peak in 2009. After 2010, the number of publications still kept slightly decreasing every year. And the number of citations also raised sharply in 2005, while, went down after 2015. Compared with the CER, CFY has a lower degree of attention, and especially there are abundant foreign publications on CER but very limited about CFY (figure 23). The articles of these two railways were both downloaded a lot on CNKI, and their number of downloads remained similar since 2010, with more than 1000 times per year (figure 24).

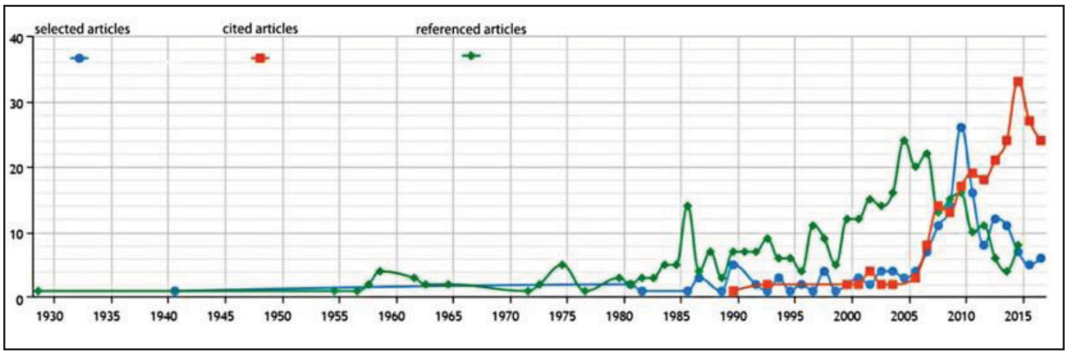


Figure 22, Number of publications of CFY on CNKI

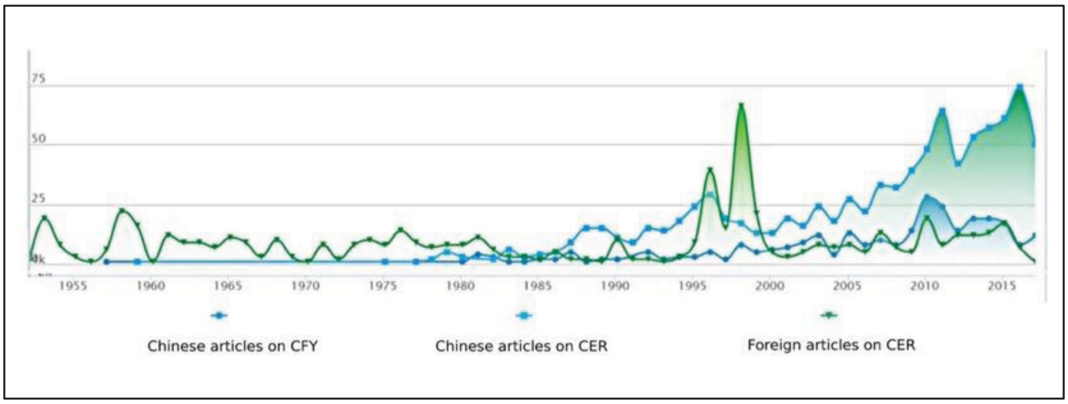


Figure 23, Comparison of publication number between CFY and CER

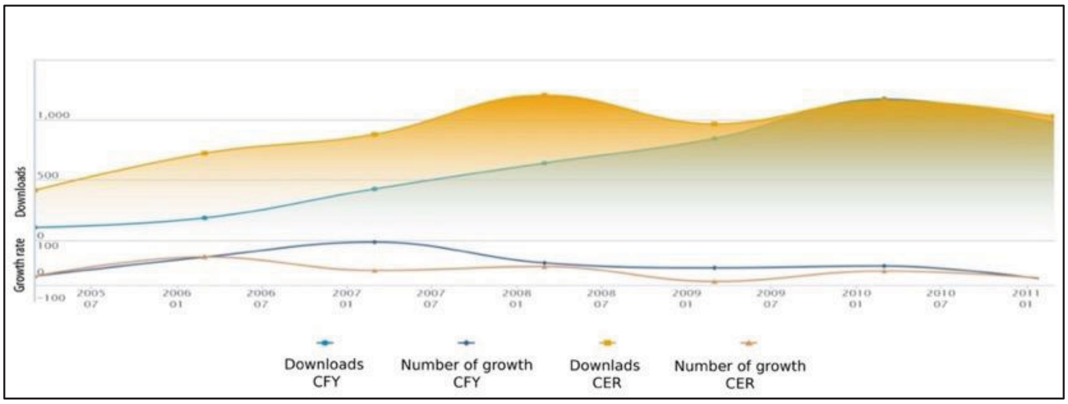
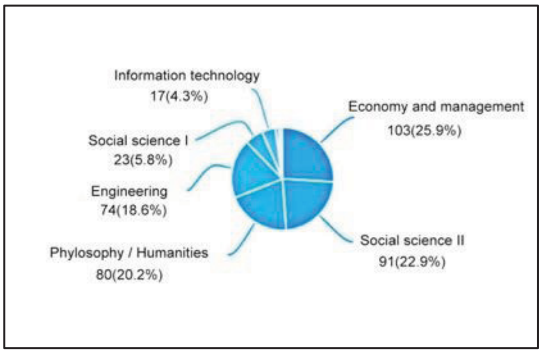


Figure 24, Comparison of the degree of attention between CFY and CER

Concerned on the selected journal articles, the analysis results refer to diverse research fields, organizations and the trend of these publications. According to the findings in figure 25, economic management and social science are predominant (48.8 %) in the fields of CFY studies, other aspects such as engineering and human sciences are also involved, making the study of CFY interdisciplinary. As for the organizations engaged in the study, the Agricultural University of Yunnan, Honghe University, Yunnan University and Yunnan Normal University are the top four organizations with the most academic publications (figure 26), which indicates that the CFY study is a regional topic mainly studied by the organizations in Yunnan province. Then, a visual analysis is also done for the distribution and connections of keywords of all the articles (figure 27). The economy of Yunnan, GBS railway, Mengzi and Namti bridge are the keywords mentioned frequently among these studies. It can be seen that the economic influence of the railway in Yunnan is always a hot topic among all the research, and Bisezhai railway station and Namti bridge are the heritage sites studied most frequently, which is in accordance with the list of current inscribed railway heritage in Yunnan.



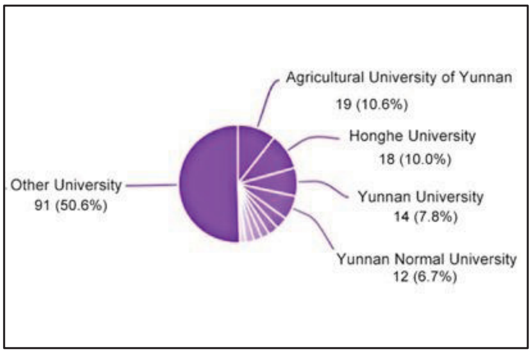


Figure 25, Distribution of disciplinary areas **Figure 26, Distribution of research bodies**

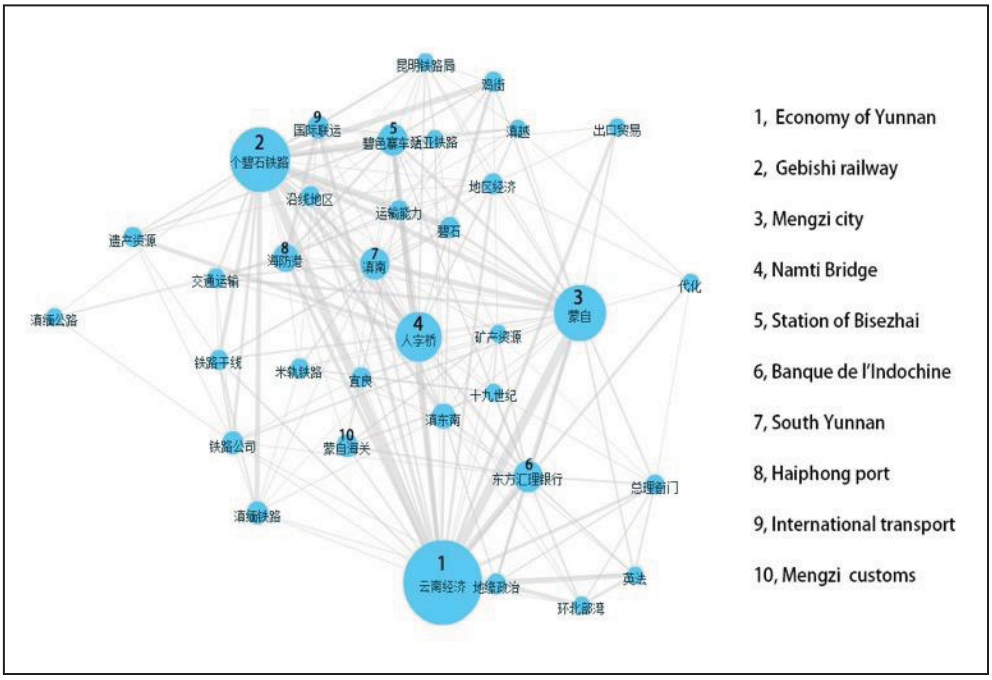


Figure 27, Connection among keywords of CFY studies

Being the first railway in south-western provinces and the first international railway in China, the value and meaning of CFY have been widely discussed from the viewpoint of history, economy, technology, culture and art (Che, 2013). Although the initial aim of constructing this railway was to expand the French colony in Southeast Asia, it was a core factor causing the changings in economy, society, ideology, culture, customs and religious ethics in Yunnan, accelerated the modernization, urbanization, and industrialization for cities along this line (Tan & Yang, 2011). During the period after the Sino-French War, colonial economy caused the disintegration of natural economy in Yunnan and the changes of its industrial structure. However, it did improve the traffic and economic condition of Yunnan, especially the conditions for developing mining industries in Yunnan. It also improved the daily convenience, introduced advanced technologies and management experiences from France, as well as more developing opportunities and international exchanges into this region (Che, 2006).

Some studies focus on the leisure value and tourism resources of this railway, from the aspects of architectural heritages, constructing technologies, natural landscapes, communism relics, multi-ethnic cultures, etc. Luo firstly proposed the research on the Yunnan-Vietnam railway heritage corridor (Luo, 2012), suggesting connecting the historical and cultural cities, scenic areas by a linear railway heritage (Li, et al., 2015). Protection and reuse of the CFY heritages is always a hot issue. The train stations and historical buildings along the Chinese section were evaluated from the aspects of architectural aesthetics and regional culture (Fan, 2008; Chen, 2011). And the distribution of historical bridges was also surveyed (Liu, 2018).

As is discussed, based on previous studies, the physical remains of railway stations are already surveyed, but the biggest problem is lack of a comprehensive coordination among the various and abundant railway heritages distributed along the 800-km route, especially for the Vietnamese section. CFY can be systematically protected as a linear heritage corridor. And the heritage type should not be limited to the physical remains of stations and bridges, but other forms of railway relics should also be involved and cared, to link the landscape elements as well as other intangible and movable relics together and to integrate them as a complete heritage system. For a comprehensive protection strategy of CFY, multi-disciplinary cooperation is also in need among landscape architecture, urban planning, human geography, archeology, as well as the spatial information technologies proposed in the next subchapter.

1.2.5 Spatial technology and Historical GIS[58]

Internet and technological applications have been emerged within the heritage sector and brought substantial changes in conservation, restoration, redevelopment and touristic reuse of cultural heritage (Guccio, et al., 2016). Spatial technology is a product of the combination of modern geodesy, mapping, computer science and spatial information, which has been widely used in the fields of environment and disaster monitoring, agriculture management, urban planning, as well as heritage protection. Geographic Information System (GIS), Remote Sensing (RS) and Global Positioning System (GPS), known as the 3S technologies, are the most important spatial technologies, among which, RS and GPS serve for collecting spatial data. And GIS is a comprehensive platform and a powerful toolset for managing, manipulating and modeling all the information provided by remote-sensing data, GPS, and other sources from the real world. These 3S technologies will be involved in this study.

Generally speaking, RS collects the near-real-time imagery about the Earth's surface through the transmission and reception of electromagnetic waves by satellites, airplanes or the sensors on other aircraft. Based on the collected multiple spectral bands imagery, the objects on the earth are enabled to be distinguished by their spectral signature. Therefore, the detected information can be applied in various studies (Campbell & Wynne 2011). Usually, when an object emerges in space, the propagation direction of electromagnetic waves will be changed by its absorption, reflection or transmission. Three types of resolutions of a sensor system are concluded: spectral resolution, radiometric resolution and temporal resolution (GSP, 2019). For

[58] This chapter is a modified version of the article "The application of GIS in railway heritage management: the case of Yunnan-Vietnam Railway" published in Proceedings of the ICA International Cartographic Association and has been reproduced here with the permission of the copyright holder.

heritage studies, RS can be used for the detection of archaeological sites, the monitoring of the environment around a heritage site and many other applications (Agapiou, et al, 2013).

GPS is a kind of satellite navigation system for autonomous geo-spatial positioning with a global coverage, originally developed by the U.S. Department of Defense for military uses, which provides services of position, navigation and timing (PNT). There are also other global navigation satellite systems, such as the Quasi-Zenith Satellite System in Japan, BeiDou Navigation Satellite System in China[59] and the Galileo satellite navigation in Europe. GPS is consisted of satellites, ground stations and receivers. This system contains 24 satellites, which take use of solar power or battery, circling the Earth every 12 hours. They continuously transmit radio signals with the time and position information. Then, a GPS receiver monitors multiple satellites (at least four satellites) and gets the precise position and timing through computing and solving equations (Remondi, 1984). For its accuracy, availability and low-cost receiver, a wide range of applications have been developed, including the transportation, telecommunication, environmental monitoring, topographic surveys, and terrestrial survey of heritages (Biasion et al., 2005).

GIS emerged in the early 1960s as the first operational GIS system was created by Roger Tomlinson[60] in Canada. GIS is not only a geographic method or tool but also a science deal with the process of representing and characterizing the real environments coded in the binary alphabet. Three aspects of geographic features are usually included in GIS, namely the geographic locations, their attributes and the relationships between them (Goodchild, 2010). In 1969, the Environmental Systems Research Institute (ESRI) was founded, providing services of spatial analysis and mapping to assist the projects of land-use and resource planning. Later, it was developed into a GIS company, and a series of commercial GIS products were generated, such as the

[59] In 2020, the global BeiDou navigation system is fulfilled and starts the global service.

[60] 1933 – 2014, an English geographer and he is known as “the father of GIS”.

famous ArcGIS Desktop, ArcGIS Online, ArcGIS Pro, etc. In 2005, Google Earth was created as a virtual globe and geographic information program with global images acquired from satellite imagery, aerial photography and 3D visualization, which makes the concept of GIS popular among ordinary users.

Since the birth of GIS, it has been connected more and more closely with history and archaeology. GIS is considered as a digital container and spatial toolbox for the documenting of comprehensive information of historical heritage for its multiple advantages in heritage studies and practices, for example, processing and analyzing a large amount of information effectively; managing data effectively through the geodatabase; interpreting information through user-friendly interfaces; sharing information through WebGIS for users all over the world. In 1992, GIS was firstly adopted in the heritage plan of UNESCO for Angkor in Cambodia. Aerial photographs and Landsat satellite were also introduced to obtain the data on archaeology, hydrology, land, climate, environment and demographics. A heritage database was built, which could successfully coordinate related administrative departments, and effectively avoid the destruction of cultural heritages. A GIS-based manual for heritage management was also published in 1999 as a methodological guide on international heritage conservation (Box, 1999).

Since then, the worldwide experience of GIS application in archaeology and cultural heritage protection has been reviewed by scholars (e.g. Petrescu, 2007). And in every process of heritage protection, GIS can provide powerful supports, assisting the heritage investigation, recording and cataloging, preservation, planning, monitoring and presentation. In practice, the archaeological site location modeling was developed in the 1990s, used GIS to predict the probability of locating heritage sites, for discovering the distribution of prehistorical settlements, and analyzing the relationship between historical activities and environmental factors (Kvamme, 1999). Historic Landscape Characterization (HLC) is used to interpret the shaping and changing of landscape character of archaeological sites (Macinnes, 2004). Cultural Resource Management based on geodatabase and spatial analysis is used for studying the historical landscape features, its spatial processing, and viewsheds (Zhang, 2010).

GIS was also combined with 3D modeling and other digital technologies, brought possibilities for the visualization of the past. The development in 3D visualization makes up for the shortcomings of 2D, which helps to increase the engagement of the users, providing a sensual experience of engagement with historical relics, improving the communication between technicians, the public, and policymakers (Yu et al., 2012). For example, the application of Augmented Reality/ Virtual Reality (AR/VR) in heritage visualization (Gillings & Goodrick, 1996), Building Information Modelling (BIM) for the visualization of historic architectural heritages and traditional villages (Saygi & Remondino, 2013), the Light Intensity Detection and Ranging (LIDAR) for heritage detecting and buffer zone establishing (Megarry et al., 2016), as well as Web mapping techniques and Mobile GIS for heritage tourism interpretation (Zhang, et al., 2015; Dhonju, et al. 2018).

It can be seen that the spatial technologies became of great importance within archaeological and historical contexts, and blooming in recent years in many practical projects and cases (Zhou et al., 2010; Hu et al., 2010; HE et al., 2015), especially when the concept of "Historical GIS" (HGIS) was developed through a series of studies in 21st century (Knowles, 2000; Kull, 2005; Gregory & Healey, 2007), which focus on studying the history spatially (Knowles, 2013) within three main fields: historical land use and the development of spatial economies; past landscapes and the changing morphology of environment; open historical sources for public uses (Knowles, 2008).

Based on the essential functions of GIS, HGIS proposes the historical geodatabase and spatial modeling for the storage, visualization, analysis and management of historical information. The digitalized data in the database overcomes the shortcomings caused by paper documents, such as space consuming, difficulty for moving, and abrasion loss. For the advantages of openness and continuity of data, strong correlation, and intuitive operation, the introduction and development of HGIS technology have fundamentally changed the way in which historical information is obtained, analyzed, managed, and displayed. It also transforms the management of historical and cultural heritage from complex, inefficient, tedious manual tasks to automated, advanced and fast operations (Huang, 2017).

With China's rich historic literature, many breakthroughs have been achieved in the studies of the combination of history, heritage and GIS, from the aspects of historical climate changes, river geomorphology, transformation of urban and rural morphology and so on (Zhang, 2018). The achievement of Chinese HGIS research can be reflected by the construction of Chinese Historical Geographic Information System (CHGIS)[61] and the Silk Road Historical Geography Information Open Platform (SRHGIS)[62]. On basis of the 3S technologies, a temporal-space big data platform is built to integrate the storage, management, application, analysis and sharing of geo-historical data of the Silk Road. Thematic sections are presented as environment, transportation, land use, commerce, ethnicity, religion, cultural relics, and cultural dissemination. It can also provide open resource data for more comprehensive academic research on the Silk Road.

Other comprehensive national-scale HGIS databases have also been built in many countries, like the British Historical Geographic Information System (GBHGIS), National Historical Geographic Information System (NHGIS) in the USA, the Digital Atlas on the History of Europe, etc. Their common features can be concluded: they extract and compile quantitative and positioning information from historical literature; establish database based on geographic graphics, tables, historical photos, ancient maps, old remote sensing images; use the online platforms to digitize historical maps, to visualize the temporal and spatial changes, making a wide range of thematic maps about administrative borders, land use/land cover change, civil adaptation to the environmental change, population distribution, urban sprawl, regional development and so on.

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[61] Website: http://chgis.fas.harvard.edu

[62] Silk road is a UNESCO site as trade routes connecting China with the West from the 2nd century BCE till the 18th century. Official website: http://www.srhgis.com

The HGIS approach was also successfully applied into the studies of railway history. Siebert (2004) discussed the methodology of the geometric representation of railway segments and junction stations, laid the foundation for mapping historical railway systems in GIS. From a national scale, in Britain, the expansion of the railway system during the nineteenth and twentieth centuries and its impact on population growth is studied by HGIS (Gregory & Schwartz, 2009). Thévenin et al. (2013) did the research on railway development and population dynamics in France. From a continental scale, in Europe, the evolution pattern of railway network is analyzed, revealing the large-scale demographic changes (Marti-Henneberg, 2013), explaining the relationship between urbanization and railway (Atack et al., 2010; Stanev, 2013). Morillas-Torné (2012) applied HGIS to create a geo-spatial database of historical railways in Europe. However, in these studies, railway is just considered as a social factor influencing the urban and economic development, but not as the object of heritage to protect.

In fact, the old railway system like CFY is an integral reality with some common characteristics: 1) the large spatial extent of territory; 2) dynamic environment; 3) complex composition of heritage elements like natural or cultural landscapes, ethnographic realities, and collective memory; 4) a massive amount of spatial data related to the heritage. This complexity makes the railway as a long linear heritage, hard to manage, requiring comprehensive coordination of all the relevant information (Tang & Zhao, 2013). For these reasons, HGIS offers excellent potential in the management of these large-scale heritages, exploring the relationships between the railway and the environment. For example, the heritage system of the Chinese Eastern Railway utilizes GIS, GPS, RS and matrix laboratory as the platform, combined with the Minimum Cumulative Resistance Model (MCRM) and the analytic hierarchy process to build a spatial pattern of heritage corridors (Tang, 2017). For the Tea Horse Road, a structured database is designed with layers of data, management, service, and application (Feng, 2016). Also, the suitability analysis with GIS is discussed in the case of the Zhangzhou Ancient Post Road (Zhan & Guo, 2015). In the case of the Grand Canal in China[63], HGIS provides functions for establishing the buffer zone for protecting the surrounding landscape, visibility analysis, overlay analysis to assess the suitability of land use, and 3D visualization to display the heritages for the public (Mao, 2008).

Thus, the HGIS and 3S technologies have much potential to support the identification, classification and further management of railway heritage. And the introduction of HGIS to the Chinese railway heritage protection in this research is a creative proposal. The research method of railway heritage protection can be innovated with the help of Web mapping to improve the tourism experience. The environment around the heritage can be reflected by the satellite imagery. The heritage identification and recording can be assisted by the tool of GPS and RS. And a GIS system designed for the railway heritage overcomes the shortcomings of the traditional heritage catalog, linking the isolated heritage assets and put them in relation with the characteristics of the natural and human environment, helping in the analysis and mapping processes (Loren-Méndez et al., 2018). The specific process of combining HGIS and 3S within the protection of CFY will be discussed in the chapter of methodology. Based on the HGIS system of CFY, further spatial analysis and touristic applications can also be achieved.

[63] A UNESCO site with a length of 1,776 km, it is the longest and the oldest canal in the world.

1.3 <u>Theoretical context</u>

1.3.1 Main conceptions

➢ Heritage

The concept of heritage was born within the meaning of temporality, which contains both notions of inheritance and transmission between the ancestors and generations. Heritage also refers to the meaning of preservation, protection, culture and value. According to the UNESCO (UNESCO, 2003), it refers to some categories:

1) Cultural heritage:

"monuments: architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, art or science;

groups of buildings: groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science;

sites: works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view" (UNESCO, 1972).

2) Natural heritage:

"natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view;

geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation;

natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty" (UNESCO,1972).

3) Mixed heritage: "if they satisfy a part or whole of the definitions of both cultural and natural heritage laid out in the convention of UNESCO" (UNESCO, 2008).

4) Cultural landscape: "a diversity of manifestations of the interaction between humankind and its natural environment. Cultural landscapes often reflect specific techniques of sustainable land-use, considering the characteristics and limits of the natural environment they are established in, and a specific spiritual relation to nature. Protection of cultural landscapes can contribute to modern techniques of sustainable land-use and can maintain or enhance natural values in the landscape. The continued existence of traditional forms of land-use supports biological diversity in many regions of the world. The protection of traditional cultural landscapes is therefore helpful in maintaining biological diversity. It includes landscape designed and created intentionally by man, organically evolved landscape and the associative cultural landscape" (UNESCO, 2008).

- Industrial heritage

Literally, IH was considered to be limited to a single building or construction, alone or associated with machines or plants remained from the industrial revolution. The official definition is clarified by the TICCIH and ICOMOS in 2003, referring to “the remains of industrial culture with historical, technological, social, architectural or scientific value, including the buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to industry such as housing, religious worship or education” (TICCIH, 2003).

The ICOMOS explained further that “IH consists of sites, structures, complexes, areas and landscapes as well as the related machinery, objects or documents that provide evidence of past or ongoing industrial processes of production, the extraction of raw materials, their transformation into goods, and the related energy and transport infrastructures. It includes both material assets-immovable and movable, and intangible dimensions such as technical know - how, the organization of work and workers, and the complex social and cultural legacy that shaped the life of communities and brought major organizational changes to entire societies and the world in general (ICOMOS, 2011)”. Thus, the definition of IH was expanded from the physical remains to a larger meaning, focusing more on the intangible parts of industrial culture and techniques.

The importance of landscape was also emphasized in some international charters for industrial heritage. “The values of industrial heritage are intrinsic to the site itself, the fabric, its components, machinery and setting, in the industrial landscape, in written documentation, and in the intangible records of industry contained in human memories and customs (TICCIH, 2003)”. Landscapes emphasize the profound connection between the cultural and natural environment, adding particular value to the industrial heritage, which should also be perceived and protected as a part of the industrial heritage (Shackel & Palus, 2006).

Besides, the historical extension of IH covers mainly from the First Industrial Revolution during the 1750s up to now. Mumford divided the modern technological development into three periods: eotechnic, paleotechnic, and neotechnic ages, referring to the innovations from agricultural age, manufacturing sectors and the Second Industrial Revolution in the field of electricity (Mumford, 1934). Narrowly speaking, the relics of IH limits to the paleotechnic and neotechnic ages, but broadly speaking, the eotechnic age and the agricultural techniques can also be included. In practice, every country has the different historical background of the industrial development. Thus, the time span of IH may be defined differently in different projects. For example, the “Industrial Heritage at Risk project” in England delimits it strictly from the Industrial Revolution to the First World War. In China, the term IH concentrates mainly on the remains of the Industrial Revolution. There are also some scholars who proposed that the industrial heritage can be classified into ancient, modern and contemporary heritage according to the Chinese history (Que, 2008). The extension of attention to industrial heritage has been gradually evolved to the late of Middle Ages, with some productive agricultural elements (mills, valleys, canals, etc.). However, it does not mean that the rural/productive heritages are included in the category of industrial heritage, which respects the difference between manual and individual land labors compared to organized labors, and the presence or absence of capital (Fontana, 2005).

- Railway heritage

Railway heritage is, undoubtedly, a kind of industrial heritage, referring to all the heritages related to railway. In practice, there are various types of railway elements considered as the railway heritage, for instance, the railway-related building and structures, the rail-line itself, locomotives, and so on. The railway bridges, platforms, railway stations, signals, tunnels, viaducts, and related factories and warehouses can be regarded as the principal part in the protection of railway heritage (Burman & Stratton, 2014).

The Riga Charter published by the European Federation of Museum & Tourist Railways (FEDECRAIL) stated that "railway heritage includes historic railways, museum railways, working railway and tram museum, tourist railway and heritage trains. The conservation of railway heritage includes the railway buildings or infrastructure, as well as the scientific and traditional technical skills. The important means of interpreting and protecting the railway heritage is to maintain all aspects of railway equipment, operate them with traditional procedures, and present them to the public" (Riga Charter, 2005). The Riga Charter emphasized the importance of not only the physical railway remains but also the related original documents, industrial skills and the ways of interpretation of railway heritage.

Railway heritage is acknowledged as a category by the ICOMOS. According to the history and engineering index, the railway heritage can be classified into main transportation lines, colonial lines, mountain railways (figure 28), narrow-gauge railways and a mixture type (Coulls, 1999). Among these, the colonial characters are mainly reflected in the forms of railway stations (figure 29). The CFY in this thesis is a complex of railway heritages, as a mix of all these four types mentioned. It is a national rail-line in the Yunnan province and the north Vietnam functioning till today. The section in Yunnan has a strongly character of mountainous topography. Then, its track gauge is one meter and it was constructed during the colonial period of French Indochina.

The UNESCO set examples for the criteria of railway heritage. The nomination of Semmering railway and Indian mountain railway focused on the its technological value to solve the major physical problems in the construction of mountain railway. And their natural beauty provides the possibility of the development for touristic and recreational use as new cultural landscape. For the nomination of Bernina Railway between Switzerland and Italy, the aspects of history, technology and landscape are evaluated, including:

"Historical value intends to the construction period: (i) early high-altitude railways up to 1882; (ii) railway structures built up to 1915; (iii) more recent railways built after 1915. Alignment: (i) largely original; (ii) slightly changed; (iii) greatly changed.

Technological value includes density of engineering structures: (i) very high; (ii) high; (iii) low. Equipment: (i) with rare/early/innovative power supply; (ii) with largely original or significantly changed superstructures; (iii) with rolling stock from the period of construction or electrification.

Landscape value refers to the difficulties and attractiveness of embedding the route in the local topography (UNESCO, 2008)."

Figure 28, A typical mountain railway on the Alps

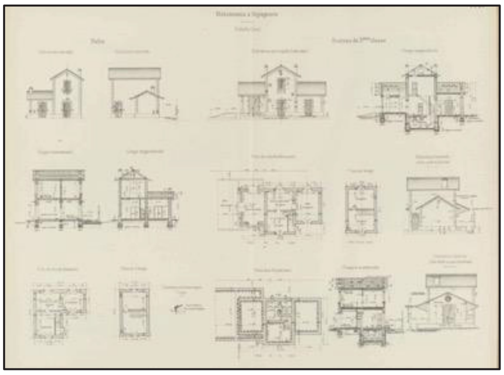

Figure 29, Design of CFY stations in French style

- Railway landscape

In certain types of tourism, the process of contemplation and enjoyment of landscape plays an important role. In the collective imagination, railways in general have always been associated with the observation or enjoyment of landscape. Nowadays, there are some historical railways or touristic trains as objectives of aesthetic enjoyment of landscapes, which combine a taste of nostalgia, curiosity for appreciating various scenes and traveling with a slower speed.

Thus, the term railway landscape or "railscape" generated and combined railway with landscape, which defines the landscape that can be observed and perceived while taking a touristic railway (Zhang et al., 2014). The railscape is characterized by its diversity and continuity in the movement, which can be divided into internal landscape and external landscape.

The internal landscape refers to the railway itself, such as the trains, railroads (structures, tracks, signals, signs, and earthwork), railway stations and other structures (bridges, tunnel, and barriers). The external landscape indicates the natural and cultural landscape along the railway. They are the main aesthetic objects by viewers during the trip. The natural landscape depends on the geographic conditions of the area where the train is passing through, which could include mountains, lakes, forests, and wetlands, as well as the changes of landform and vegetation. The cultural landscape is mainly interpreted as towns, temples, buildings, roads, villages, croplands and other artificial elements and historical remains (Paul, 2000; Gao, et al., 2012).

- Greenway and heritage corridor

Greenway is generated from the idea of boulevards or parkways in the late 19th century. Based on the theory of landscape ecology, greenway had been widely developed and applied into landscape planning in Europe and America since the 1990s. It was firstly defined as "a network providing people with access to open spaces, linking the rural and urban spaces together" by the President's Commission on Americans Outdoors (1987). Later, a comprehensive definition was proposed based on previous landscape planning experiences as "networks of land planned, designed and managed for ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use" (Ahern, 1995). And Little classified greenway into five categories: urban riverside; recreational greenways; ecological corridors; scenic and historic routes; comprehensive greenway systems (Little, 1995). While in Chinese academy, due to the long history of agricultural cultivation, greenway is considered as a linear landscape composed of green elements associated with waterways, transportation systems, as well as agricultural fields, aimed to protect the arable lands and green areas from urban and population pressure and other natural disasters (Yu et al., 2006).

The number of literatures of greenway was increasing rapidly, and it was introduced in ecosystem protection, historical and cultural resources redevelopment and urban recreational planning. Despite the varied geographical conditions, policy orientation, landscape characteristics and demands of shareholders, greenway became one of the main theories and guides for the practice of urban renewal and natural conservation, and usually, each project developed their own standard, strategy and approach to find the suitable solution and to meet their needs (Conine et al., 2004; Fabós, 2004).

In the field of heritage protection, some projects of heritage conservation and management relate to large-scale and complicated heritage systems, including canyons, canals, roads and railway lines, as the manifestations of the connection with greenway. The "heritage corridor" as a planning method was introduced based on greenway theory. It defines a linear landscape with a collection of cultural resources, which comes along with distinct economic centers, booming touristic activities, adaptive reuse of historical heritages, as well as the facilities for leisure activities (Searns, 1995).

Combining ecological protection with the overall protection of cultural heritage, the heritage corridors is a multi-objective method for heritage protection, regional revitalization, heritage tourism and environmental education. It integrates the protection of cultural relics, ecological protection and leisure activities, connecting multiple heritage sites in series, emphasizes the cultural significance and natural value of the heritage, and the ability to balance natural ecosystems and economic values. It provided new perspectives, strategies and approaches for the practice of heritage planning since the end of the 20th century (Christina, 1993), such as the cases of building the Illinois and Michigan Canal National Heritage Corridor, Erie Canalway National Heritage Corridor, South Carolina National Heritage Corridor and so on.

Heritage corridor is a linear heritage area, which makes it different from a scenic area or historical and cultural town. The scale of a heritage corridor may differ within a few to hundreds of kilometers. It is also a comprehensive heritage system combining nature, economy, history and culture. The heritage corridor can be divided into four components: heritage resources as the core, greenway as the ecological infrastructures, transportation system, and interpretation systems (Wang & Sun, 2001; Gong, et al., 2016). Flink & Searns (1993) emphasized that a heritage corridor must contain historical importance, architectural or engineering value, economic potential and ecological importance for the whole area. And the primary principals of heritage corridor planning were proposed by Ji & Shao (2017):

1) Multifunction: based on the green infrastructure, the ecosystem services need to be maximized for the whole region, such as flood control, public health services, etc.

2) Connection: all the subsystems of heritage corridor are not independent but need to be intertwined with each other as the significant elements of landscape ecology (patch, corridor, edge, and matrix). The connections among cities, nature, users, heritage sites and open spaces will also be built in the system.

3) Sustainability: the heritage corridor needs to be flexible and adaptable to the dynamic changes, which means it can effectively relieve the possible influences from the ecological, social, economic and cultural factors, with high efficiency in meeting the constantly changing needs of citizens.

In China, Wang & Sun (2001) firstly introduced the cultural connotation, protection management methods, and selection criteria of American heritage corridor to China. Then, some heritage sites successfully applied the theory of heritage corridor into their protective practices, for example, the Grand Canal (Shi, 2009), Yellow River heritage (Zhu & Jiang, 2013), and the Great Wall of Ming (Wang, 2014).

In Europe, the cultural route implies the similar meaning with heritage corridor, which defines a dynamic cultural landscape route referring to “a land, water, mixed or other types of route, which is physically determined and characterized by having its own specific and historic dynamics and functionality; showing interactive movements of people as well as multi-dimensional, continuous and reciprocal exchanges of goods, ideas, knowledge and values within or between countries and regions over significant periods of time; and thereby generating a cross-fertilization of the cultures in space and time, which is reflected both in its tangible and intangible heritage” (Martorell-Carreño, 2003).

The cultural route and heritage corridor are both based on the cultural communication in the history, focusing on not only the cultural heritage along the route, but also to the related communities, culture and intangible heritage. They provide a regional cooperative platform for a comprehensive protection. At the same time, the cultural landscapes with dynamic characteristics, ecological protection, regional revitalization, and tourism development are integrated into this process. In this thesis, the difference between the cultural route and heritage corridor will not be distinguished further. The current situation and character of CFY, including the abundant heritage resources, landscape and environmental elements along the route, make it possible to be combined with the theory of heritage corridor for the protection and development of its railway heritages.

- Buffer zone

The concept of buffer zone was born from the activities of the protection of natural parks, formed a series of theories till the 1970s and applied into the protection of cultural heritage as well. In the operational guidelines of UNESCO, "a buffer zone is an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development in order to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection. The area constituting the buffer zone should be determined in each case through appropriate mechanisms. Details on the size, characteristics and authorized uses of a buffer zone, as well as a map indicating the precise boundaries of the property and its buffer zone, should be provided in the nomination" (UNESCO, 2019).

Based on the building of buffer zone, its features can be performed: "protection of the outstanding universal value (OUV) of the World Heritage property; enhancement of the outstanding universal value of the World Heritage property; completion of the measures to protect or manage the outstanding universal value associated with a World Heritage property, for instance by addressing dispersed values or addressing specific threats that arise from wider land use surrounding the property; defining and protecting the setting of a World Heritage property, including the setting of Cultural Landscapes; complementing the measures for protection of the World Heritage property; promoting activities within the buffer zone that enhance the World Heritage property while bringing benefits to the local community" (Martin, 2008).

For creating buffer zone, Ebregt & De Greve (2000) classified the buffer zone into nine types: traditional use zone, forest buffer zone, economic buffer zone, physical buffer zone, streamside buffer zone, social buffer zone, sanitary buffer zone, fire buffer zone and geopolitical buffer zone, also provided the successful and failing experiences of the building the buffer zone. It is noticed that different heritage sites have different cultural, political and economic backgrounds, which requires scientific methods of planning buffer zone in different cases. For example, the models of ecosystem process are used to create the buffer zone of natural heritage sites, and visual analysis is used in the case of cultural heritage, such as the London View Management Framework defined the viewing corridor, setting consultation area, and background consultation area for protecting the urban heritages in London (Chen & Wei, 2018). And the planning of evacuation areas based on the passenger flow is another way for building the buffer zone in the Chinese scenic areas (Zhuang & Yang, 2012).

In China, a buffer zone for heritage protection can be divided into two parts: core zone, and constructive control area, in some cases also including environmental buffer and landscape buffer. For protecting the architectural buildings, the visual corridor (Distance) and its relationship with the heritage height (Height) must be considered, namely the core zone covers the area with the value of Distance/ Height ≤ 2, the constructive control area with the value ≤ 3, and the landscape buffer with the value ≤ 5 (Chen, 2009). Xie (2015) proposed a method based on the environmental capacity to build the buffer zone for the historic cities through assessing the key factors which influencing the environmental capacity of the city.

As for the buffer zone of heritage corridor, Chines scholars divided the heritage corridor system into core heritage sites, buffer zones and spatial connections, using the Minimum Cumulative Resistance Model (MCRM) with the help of GIS and RS to make the suitability analysis for heritage tourism. Namely, based on the touristic experience in a horizontal movement in space, the land elements produce resistance for the heritage activities, a bigger resistance means the less suitability for the touristic activity; on the contrary, the area with a smaller resistance means a higher suitability for establishing a heritage corridor for heritage activities (Yu, et al, 2005; Zhan & Guo, 2015). There are also other ways for the construction of heritage corridor, for example, using the Kernel Density analysis to divide the heritage density (Wang & Ma, 2017). In this research, the MCRM method is introduced for the CFY heritage corridor in the next chapter.

1.3.2 Values of railway heritage

Generally speaking, understanding the values of heritage is the central part of the heritage protection procedure. The heritage value needs to be identified, evaluated, and reutilized for the heritage redevelopment (Fredheim & Khalaf, 2016). The value of a cultural heritage can be classified as 1) cultural values including the documentary, aesthetic, historic, archaeological, architectural, landscape, ecological, and township value; 2) value of use including the social, economic, functional and political value; 3) emotional meaning including the wonder, continuity and identity (Feilden, 1979).

An industrial heritage contains various values from the aspects of history, social-culture, aesthetics, economy, technology, spirit and so on. The ICOSMO proposed criteria for the selection of significant historical railways, which means, in general, a heritage railway can to be identified from: "the representativeness of a creative engineering work; technological and scientific innovation; typical example for other railway projects; economic and social impacts in the history (Coulls, 1999)". The European Federation of Museum & Tourist Railways listed the similar criteria for assessing the railway heritage, including the representativeness and uniqueness; technical values in the history; historical meaning in the development; social-economic impact and regional or national significance; its correlation with important historical events and person (FEDECRAIL, 2005).

As for railway heritage, its values can be explained and understood as follows:

- Historical value

Every railway has its historical background and stories behind it. Railway and its related techniques are important evidence for the industrial revolution. The historical value connects with specific historical persons, events and activities, which is the basis for the evaluation of railway heritage value. The comparison of specific historical conditions among railways from the same period can reflect its outstanding contributions. And the historical activities of human beings at this period can influence the originality and authenticity of the railway. For example, the colonial railways are the products of colonial activities, which contains the information on colonial policy, construction, and the relation between colonists and colonies. The early construction of railways in the modern history of China connected closely with the colonial activities by the Westerners. Thus, analyzing their historical value needs to be linked with this history and their historical roles in the past.

For the CFY, its historical value lies on its historical contribution to the industrial development of Yunnan and Vietnam, and its meaning as the evidence for the French colonial history and the Chinese revolutionary events. The railway heritages are the physical manifestations of the historical value, especially, the relics conserved in the museum and archive are the critical forms to record and reflect its historic value (figure 30).

Figure 30, Railway history explained in the Yunnan Railway Museum

- Technological value

Different age is characterized by different railway techniques, such as the selection of railway course, track bed constructing, railway management, and related structures and equipment. Engineering technology is the core criteria for the identification of railway heritage, which is also a special characteristic making it different from other industrial heritages. The specific index for mountainous railway can be compared through the steep gradients, height, number of curves and loops, the layout on slopes, setting-back tracks, safety measures, the construction of bridges and tunnels, as well as the techniques of locomotive (figure 31). SU summarized four ways of technical solutions for the mountain railways: "horseshoe curve and U-turn line, loop and spiral loop, switch back or zig-zag line, and special designed engine" which can be regarded as indexes for evaluating the technical value of historical railways (Su, 2011).

The UNESCO used to take different cases of railway technique for the comparison of the railway heritage through their "year of construction; engineering difficulty and attractiveness of embedding the route in the local topography; modification alignment; and the density of important engineering structures" (UNESCO, 2005). Jiang et al. also proposed that the technical difficulty is an index reflecting the technical value of a railway heritage, and it is also related to the historical value of railway, namely during the earlier the construction in the railway history, there were more technical difficulties to resolve for the engineers (Jiang et al., 2019)

Another example is the Ffestiniog Railway in the UK, which was the earliest opened narrow-gauge railways with a width of only 59 cm. The narrow-gauge transportation meets the changing steep terrain, makes it a representative mountain railway heritage. It can be seen that narrow-gauge was an important technique in the 19th century, representing the technical value of historical railways.

Figure 31, Locomotive in the railway museum showing the technical value

In the case of mountain railways in India, the UNESCO described that “these railways are outstanding examples of the interchange of values on developments in technology, representing different phases of the development in high mountain areas, and the impact of the innovative transportation system on the social and economic development of a multicultural region, which was to serve as a model for similar developments in many parts of the world” (UNESCO, 1999). Besides, outstanding persons such as the famous designer and engineers in the construction of railway can also be regarded as part of the technological value of historical railways.

Thus, the technological value of CFY can be reflected by the engineering index for constructing this mountainous railway, and the techniques used in constructing railway stations, bridges and tunnels. Another indicator introduced in this study for the railway heritage evaluation is the difficulties met during the railway construction, including climatic, sanitary and topographic obstructions.

- Landscape value

Landscape refers to the appearance of areas on Earth that can be viewed, as a result of a synthesis of people and the land of the living, which can be perceived differently by the individuals according to their cultural backgrounds (Council of Europe, 2000). The meaning of landscape covers both the human built environments and the natural or semi-natural territories. As a key element of social well-being and cultural identity, landscape always influences the quality of daily life, which needs to be valued for economic, cultural, ecological, recreational, and educational reasons. And its value lies in its construction, integrity, diversity, aesthetics and environmental quality (Gulinck, et al., 2001), which implies that landscape should be understood as a system from an extensive environment but not as isolated features (Selman, 2006).

The relationship between the railway and landscape is close, which was transited from opposition to integration, and still changing as time goes by. As transportation infrastructure, railway is a pioneer of modern techniques, it also created access to the wild or natural landscapes. Railway is not only a tool for perceiving the landscape outside of the train, but also an object of landscape aesthetics. At the same time, it is also the creator and reformer of landscape. Dating back to the early days of the invention of railway and trains, as a large industrial machine, they were regarded as a conflict with the picturesque and pastoral landscape, when the landscape aesthetic was tied to the picturesque natural views and the landscape paintings revolved the themes in natural elements, such as hills, woods and rocks. The early experience with train was described as "strange, unpleasant, bored, anxious, and fearful" by the clients, and the early visitors even did not know how to enjoy the landscape on a moving train (Thompson, 2012; Ma, 2013).

With the development and publicity of the railway through poster, travel literature and other advertising methods, its negative image had gradually changed into positive, people began to accept it as a daily means of transportation, and the attractiveness of railway travel had also increased. For example, the Ministry of Railways of China has issued a number of railway travel guides about the Daoqing railway, Jinghan railway

Jiaoji Railway and so on. The new spatio-temporal network of railway unsettled the understanding of space and time, as well as the experience of landscape between city, countryside, even the uncultivated places in the past. Especially, it translated the life of human beings into an era of modernity, with new modes of feeling, observing and socializing (Schivelbusch, 1979). By analysing some paintings, it is found that railway is no longer contradict with the landscape aesthetic standards, became one of the internal elements of landscape (Pacey, 2002). The elements such as railways, steam locomotives, and bridges have even been widely disseminated in landscape paintings and travel publications in the 20th century, especially during the Neo-Romantic movement in the middle of the 20th century, 'picturesque railway' is used to describe this tendency of merging between railway and landscape. For example, Van Gogh's famous oil painting "Landscape with Carriage and Train" (figure 32) depicts the merging between rural landscape and a train passing through. And Lam (2011) also used the examples of railways in Canada proved the assimilation of railway into the wildness of environment.

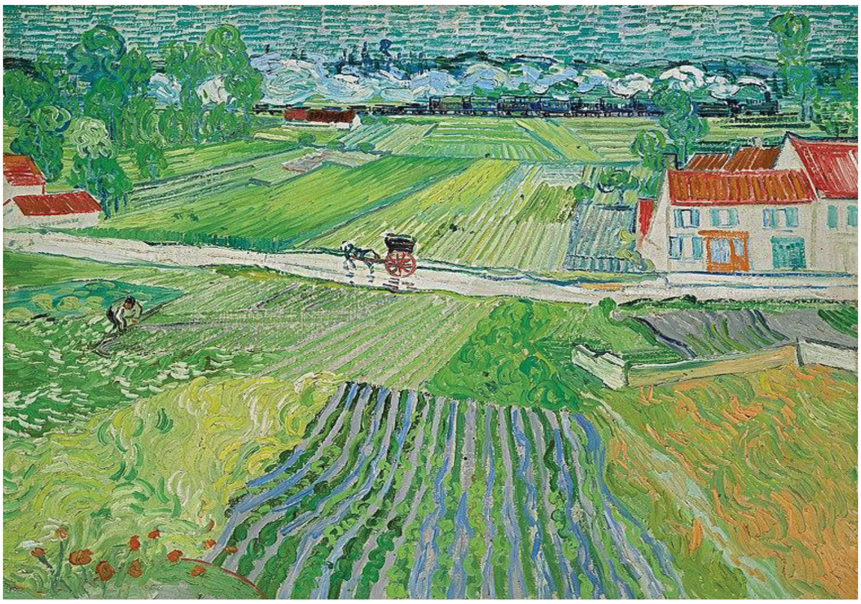

Figure 32, Landscape with Carriage and Train (Vincent van Gogh, 1890)

It is seen that landscape is an integral part of industrial heritage/railway heritage for its great value as a part of industrial history. A place has high landscape value, usually leading to a high touristic value. The quality of landscape is also a crucial factor for the railway attractiveness in heritage tourism to experience both the natural part of landscape and the memories from industrial time, and therefore to aid the economic development. In the process of selection of railway heritage by UNESCO, the significance of landscape is highlighted in the cases of Semmering Railway, Darjeeling Railway and Bernina railway. In this thesis, railway landscape is considered as a part of the railway heritage during the heritage protection and redevelopment. And various landscape resources will be included in the railway heritage system of Yunnan-Vietnam railway. The landscape value of CFY is mainly reflected from the multiple sceneries that the railway tour provides and whether the scenic sites can be observed by the visitors on the train.

- Architectural and aesthetic value

Architectural features refer to the reflection of a culture, history and the local geographical conditions. Railway stations are the main elements for studying the previous architectural aesthetic, as one of the earliest types of industrial heritage to be noticed by the public. Along the railway route, stations are the most visible structures to represent the previous industrial and artistic features. The architectural value of railway statins is reflected from architectural style, architectural culture and detailed decorations. For example, the old railway station in Jinan (Shandong, China) is under strong influence of the German Art Nouveau as well as the Chinese folk culture. Its structure, shape and decorations are highlighted by the European medieval religious philosophy, which makes them excellent modern transportation buildings with high architectural value in China (Li, 2014).

Also, for the CFY, its architectural and aesthetic value concentrated on the style of the well-preserved stations. The French stations have some common features such as the red roof, yellow walls and some French decorations in detail (figure 33-34). And the rebuilt stations in the 1950s have the characteristics of the Chinese arts, showing an obvious comparison with the French styles. Besides, the architectural value can be also seen in the construction of railway bridges and other historical buildings.

Figure 33, French-style station showing the architectural value

Figure 34, French clock as a building decoration

- Social-economic value

The railway heritage itself played the role of transportation in the history, no matter it is a method of mining transmission, forest railway as the case of Alishan railway in Taiwan, or the cross-regional railway such as the CFY and CER. They all provided the provision of goods and services, which brought economic benefits for the industrial development or the whole area, even as one of the important driving forces on transforming agricultural society into industrial modern society. The cultural meaning of a historical railway is also reflected from the communications along the railway areas, such as its functions for connecting the ethnic minorities, current public attitude on railway, the spread of technologies among different countries, the foreign participation in the process of railway construction, and the relationship between colonists and colonies (Jiang et al., 2019).

Then, in contemporary time, lots of the historical railways were reutilized and developed as tourist attractions (figure 35), which generates economic activities in the area by creating job opportunities related to tourism, such as catering, accommodation and retails. In different cases, the railway owns specific values. For example, a railway passing through the area with good visual quality provides it with aesthetic value. The railway remains exhibited in the museum have the educational value. For the locals who are living there, the railway heritage can be a part of their life, especially for the former railway workers, the historical railway is a part of cultural identity for them. Thus, railway heritage provides also social identity and spiritual emotions for the local residents (figure 36).

As for the value of Yunnan-Vietnam railway, it has been widely studied. Zhang (2013) concluded that the CFY owns great historical, cultural, touristic and economic values. The regions that CFY passing through have also landscape value and ecological value (Chen, et al., 2013). Further heritage evaluation will be based on the values of CFY from the perspective of landscape, ecology, technology, social-economy and tourism.

Figure 35, A stop on construction for the touristic train in Kaiyuan (Yunnan)

Figure 36, Railway market as a part of daily life in Baihe (Yunnan)

1.3.3 Railway attraction in tourism

In tourism, the heritage has been connected with the cultural and natural aspects of a tourist destination. For different visitors or individuals, heritage attracts the visitors from different aspects from the social, economic, cultural, and political factors, among which the feeling of nostalgia, the desire for protecting the past relics and enjoying the environment can be the most common reasons for heritage tourism (Prentice, 1993). Cooper et al. (1993) defined four attributes of touristic attractiveness, including the attractions of cultural or natural sites, access to the destination, amenities and ancillary services in the touristic areas.

The transportation methods were regarded as accelerators of the development of tourism. The transport technology has been evolved from ancient times to now, changed from horse and wind power, the steam engine, internal combustion engine, and the invention of the jet engine (Tolley & Turton, 1995). In the 19th century, traveling by trains was the dominant form of mass public transport. After the golden age of railway development in the early 20th century, the railway sector experienced a quick decline in the competition with road and air transportation, seeing the decline of passenger numbers and the loss of primary position of rail travel in tourism in the 20th century.

Currently, these transportation methods have their indispensable positions in the tourism market. Car and bus traveling are suitable for short-term tours for their flexibility and independence. And airplane has a fast and comfortable service. Comparing with the car and airplane, moving with trains is favored for its lower price, larger carrying capacity and lower environmental emissions, which his described as a safe, green and romantic method of traveling, but the railway infrastructure is not flexible (Duval, 2007). As scholars revealed that people choose railway as a method for traveling for saving money, enjoying natural views, making friends along the route, safety reasons and avoiding traffic and so on (Yiamjanya, 2020). Some research focuses on the tourists' satisfaction with railway tourism (Eboli & Mazzulla, 2015). A few indexes are used to measure the railway travel, such as the frequency of trains, tickets availability, availability of staff on trains, punctuality and reliability (EC, 2013).

Transport itself can also be a tourist attraction. The value of old railways is reflected in the social, economic, technical, political and cultural influences in the history, given them identity as heritage and attractions in tourism (Coulls, 1999). Besides, revitalization of the old railways as tourist attractions can also improve the local economy, the local living standard, and develop the railway tourism. Different historical railways have their own attractiveness, for example, the forest railway and mountain railways are characterized by the natural landscapes, and other railway routes with deserted railway stations and viaducts can be renovated as railway attractions for tourists. Tillman (2002) notes that conservation and recreation are two topics for the railway tourism. Orbasli & Woodward (2008) found out that the cultural significance, political situations and landscape value of railway attracts the tourists. Gardzińska (2018) stated that railway elements could be combined with other cultural and natural sites as touristic attractions. A comparison is made among the current three railway heritage in the World heritage list to show their main attractiveness, which are mainly noted by their mountainous natural landscapes (Pryce, et al., 2013).

Since the 1970s, a resurgence of traveling by train has been currently happening and railway tourism became special interest tourism. More attention was gained on the reuse of some old rail-lines as tourism-oriented facilities, namely the touristic train, also scenic railway or tourist railway (figure 37-38). It refers to the train on the purpose of transporting tourists for recreation, scenic tour and heritage experience, but not for a regular transportation. There are two motives for the origin of the scenic railway, namely exploring nature and protecting railway/industrial heritage (Auphan, 2005; STRMTG, 2017). They have some common characteristics: shorter driving routes and low speed; the good quality of natural scenery along the path; specially designed sightseeing cabin (figure 39) and flexible operating hours (Blancheton, & Marchi, 2013). According to the characteristic of touristic trains, it can be classified into four categories: sightseeing train, entertainment train, railway museum and other local railways (Marchi, 2007).

Figure 37, Bernina railway as a typical scenic railway in Switzerland

Figure 38, Darjeeling railway (left) and Semmering railway (right)

And a successful touristic train requires to meet the attributes: 1) it needs to provide a pleasant journey along an attractive route, also connecting with other touristic attractions. 2) The agreement among the stakeholders such as local communities, government, potential visitors, and railfans needs to be confirmed. 3) the touristic train needs to contribute positively to the economic development of the region. 4) Objective authenticity needs to be protected to satisfy the needs of various railway visitors. 5) the railway should be interpreted and presented consistently with the perceptions of locals and visitors (Xie, 2006; Bhati et al., 2014). For improving the railway journal experience, there are also some studies: Oliveira et al. (2019)

proposed the up-to-date information and customized services based on the mobile technologies, as well as other factors such as price, safety, trip planning and the railway services (Maskeliūnaitė & Sivilevičius, 2012).

Figure 39, Transparent sightseeing cabin on the Bernina railway

Looking into the tourist attraction of CFY, it lies on the abundant railway remains along the route and the scenic quality, including both cultural and natural views in this region. Currently, the main tourist attractions known among the tourists are the railway relics including the Yunnan Railway Museum, touristic train (Kunming-Wangjiaying, Kaiyuan-Data), railway intersections (between Mayuan and Shizui), Bisezhai Railway Station, Zhicun Railway Station, Luoshuidong tunnel, Yulin Qikong Bridge, Sichahe line, Namti Bridge, Laogukou, Wantang Waterfall, Baizhai Bridge, Baihe Bridge, Xiaolongtan Bridge, China-Vietnam Railway Bridge (figure 40), Longbian Bridge (figure 41), Hanoi train street, Haiphong Railway Station and so on. CFY is also passing through other types of landscapes, like urban and rural views, riverside and mountain landscapes, which are always recorded by the photos taken by tourists, but seldom studied by the scholars.

Figure 40, China-Vietnam Railway Bridge on the boundary

Figure 41, Longbien Bridge over the Red River

Due to the poor relevance among those tourist attractions of CFY, most of the travelers would like to choose only several individual sites along the route. Based on the comments and reviews on the travel websites[64], the most popular sites for the CFY tourists are the Namti bridge, Bisezhai station in Yunnan and the Longbien Bridge in Hanoi, which earned most comments on the internet. On comparison, other sites receive extremely limited reviews. The railfans are the main visitors of CFY heritage sites. Searching for the keywords of "Yunnan-Vietnam Railway" on the Chinese travel website - Mafengwo, there are a total of 183 related travel journals, accounting for only 0.15% (183 /121,156) of all travel journals in Yunnan Province. The 75 most relevant travel journals are selected for further keywords analysis. Table 5-6 show the score made by tourists and a result of keywords analysis, containing the extraction of positives and negative keywords emerged in the reviews and comments. It shows that the characteristic of the combination of railway history with the natural views along the route attracts the tourists to come. Then, there are some aspects in the tourism needs to be improved, such as the danger of hiking along the rail, pollutions caused by visitors, uncomfortable climatic conditions in the summer, management problems, abandoned railway stations, poor accessibility for the heritage sites, etc.

Table 5, Touristic records and scores of Yunnan-Vietnam Railway attractions

Table 6, Keywords analysis of tourists' comments on CFY

[64] Trip Advisor: https://www.tripadvisor.cn/
Mafengwo website: http://www.mafengwo.cn/ (search time: 2018/06/20).

1.3.4 Theoretical framework

For the main goals of this research, it aims to 1) gain a deep understanding of the historical development and value of the Yunnan-Vietnam Railway; 2) through an extensive collection of various historical and contemporary data and materials, based on the heritage corridor theory and HGIS research method, establish a railway heritage database for the integrative storage of spatial data and non-spatial data, finally implement the CFY heritage corridor system; 3) based on the building of heritage system, complete the heritage classification, assessment, and touristic interpretation of the CFY heritages.

The framework of this research is shown in figure 42. This thesis follows a traditional thesis structure, providing a systematic account of the CFY research, which is consisted of five main chapters and each chapter with a few subchapters. The first chapter is the research background, which explains the purpose of study, importance and urgency for the CFY protection, and the literature review about industrial archaeology, railway history and the spatial technologies. The main problems and opportunities that CFY and related regions faced with are figured out. Then, it defines some important concepts in this research, including the meaning of heritage, industrial heritage, railway heritage, railway landscape, buffer zone, cultural route and heritage corridor, analyzed the value of CFY-related heritages and the attractions of railway heritage in the tourism. This chapter provides a scientific basis for further discussion of the topic of railway heritage and its relationship with spatial technologies.

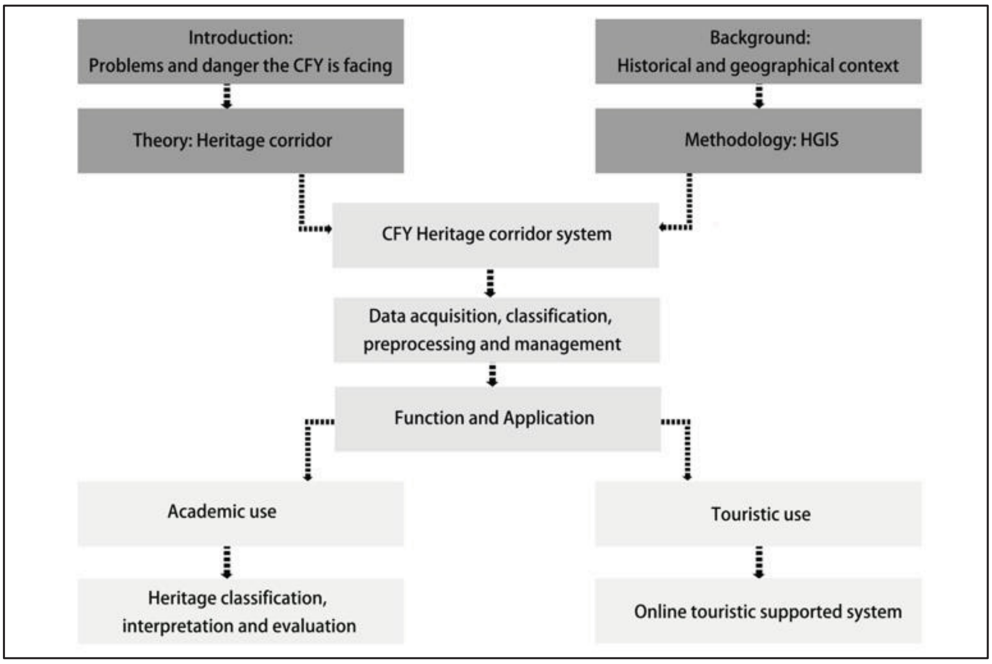

Figure 42, Framework of research

The second chapter focuses on the contexts for the study area from a perspective of history and geography. It introduces the territorial and historical backgrounds in Yunnan and North Vietnam. The general geographical conditions are displayed with maps, including climate, land relief, hydrography, ecology, soil and land, and the touristic resources in this area. Then, a history related to the whole region and the CFY is explained, mainly from the early colonial activities in Vietnam to the European explorations in Yunnan, and the process of the construction of CFY, seeing a dynamic relation between China, Vietnam, France, as well as Japan during the WWII.

The third chapter discusses the methodology of this research. HGIS is introduced as the main method to build the CFY heritage corridor. During this process, the steps of data acquisition, classification and data preprocessing and data management are specified according to the main types of GIS data (vector, thematic raster, remote sensing imagery and non-spatial data). Then, historical documents, including historical texts, photos and maps, associated with online open data, big data from internet and social media, and the data from fieldwork are the main sources for this research. After the classification of data by data format and theme, they are also pre-processed to remove the errors and redundancy, to make them the propriate formats for further spatial analysis. By georeferencing and digitalization, the historical data from photos and maps are also imported into GIS. Then, all the raster data and vector data are organized and managed in the GeoPackage as a form of geodatabase.

For building the heritage corridor, the MCRM model is used to analyze the suitability of heritage tourism based on the land use type in the study area. The heritage corridor is composed of three levels, namely the core area (width of 2 km), buffer zone (width of 20 km) and its background. And its spatial structure can be considered as the heritage cores connected by the CFY line. After the building the heritage corridor, the heritage classification is fulfilled, and the heritage evaluation is made from the aspects of landscape, ecology, technology, social culture and tourism. In this process, GIS integrates AHP and Delphi method as a spatial integrated assessment method for the CFY heritage evaluation.

Chapter IV further explains the applications based on the CFY heritage corridor. Namely, the basic mapping functions can be done with the comprehensive data in the heritage database. With the help of WebGIS (ArcGIS online and Leaflet), the heritage data can be visualized, especially for the heritage photos and fieldwork records, the WebGIS provides a platform to view the heritage sites in detail. For supporting tourism activities, some applications can be developed to find the related heritage information on the designed webpage. For other academic uses, all the data will also be shared through the ArcGIS online as open sources.

Finally, the shortcomings and problems met in this study are clarified, namely, the method of collect questionnaire needs to be improved; the accuracy of the localization of historical photos is still low, which needs further fieldwork and studies cooperated with other scholars; and the update of the data in the heritage database needs to be considered in the future research. Then, some suggestions are also made for the protection and management of Chinese railway heritage from the perspectives of the introduction of geo-historical approach for railway heritage studies, the creation of a national railway heritage database and the further study on the relationship between landscape and railway.

1.3.5 Creative points

Firstly, for the Yunnan-Vietnam Railway studies, the majority of previous research is based on Chinese literature, focusing on its historical, cultural and political influences. The original documents conserved in the archives in France have seldom been studied by Chinese academics. The data and documents used in this study are collected by four ways: the published research results about the heritages along Yunnan Vietnam Railway; the original documents about the engineering history, the historical maps and photos from French archives; the open resources about the geographical information for Yunnan and Vietnam; the data collected by the fieldwork by the author through photo observation and recording. This research is done in France, Yunnan and Vietnam from an international perspective, based on various data sources in Chinese, French and English languages. The research breadth in this thesis has never been touched in previous studies on CFY. Especially, the original documents of historical photos and maps of CFY as movable heritage are also considered as a part of the heritage of CFY corridor and the application of these historical images into this study makes it groundbreaking.

Secondly, this research combines spatial technologies with the heritage protection theories and practices. The former methodology of CFY research is mainly qualitative, thus, GIS and HGIS are introduced as a quantitative tool for constructing and evaluating the heritage of CFY, to analyze the heritage elements of CFY from a geo-historical perspective. GIS also integrates other methods such as Analytic Hierarchy Process and the Minimum Cumulative Resistance Model in the process of corridor construction and heritage evaluation. The comprehensive heritage data, along with other spatial data in the CFY regions are digitalized and imported in the heritage database. The building of the heritage system with the help of GIS and WebGIS is significant to support the future tourism planning, heritage redevelopment and government decision-making, which is another creative point in this research.

Last but not least, the comprehensive strategy for railway heritage protection discussed in this thesis integrates heritage corridor with heritage evaluation tool and touristic redevelopment, which is another creative point. The previous research emphasized the analysis of the technical value of industrial heritage, but the concept of heritage corridor put the heritages in a larger background, seeing cultural and natural elements in the corridor closely linked with each other, which are meant for large-scale heritage protection. An assessment tool for heritage corridor is introduced, discussing the indicators for assessing various factors along the railway heritage, especially landscape indicators are also regarded as one of the components of the heritage value of CFY.

CHAPTER 2. TERRITORIAL AND HISTORICAL CONTEXT

2.1 Territorial context

Yunnan, 21° 09′ N - 29° 15′ N, 97° 32′ E - 106° 12′ E, with an area of nearly 394,000 km^2, is located in the southwest of China, named after the "South of the Clouds."[65] It borders Myanmar, Vietnam, and Laos, being famous for its abundant natural resources and rich biodiversity. The cultural and natural diversity makes it special and unique in China, containing three natural heritages and two cultural heritages inscribed by UNESCO[66]. For a long time in history, Yunnan kept relatively independent for its particular position in the southwest frontier and the multi-ethnic characteristics. But it interacted well with the Han culture[67], Tibet culture and other ethnic cultures. It has also remained a close relationship and a long history of communication with the Southeast Asian countries through the Ancient Tea Horse Road[68], as well as the Yunnan-Vietnam Railway in this study.

Vietnam, about 331,000 km^2, is one of the countries undergoing the process of industrialization on the Indochina peninsula, 102° 10′ E - 109° 30′ E, 8° 30′ N - 23° 22′ N, bordering Yunnan and Guangxi provinces of China to the north, South China Sea to its east and Gulf of Thailand to its southwest. It is a mountainous country with

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[65] In Chinese, it is named as "云南".

[66] They are Old Town of Lijiang, Three Parallel Rivers of Yunnan Protected Areas, South China Karst & Stone Forest, Chengjiang Fossil Site and the Cultural Landscape of Honghe Hani Rice Terraces/Yuanyang.

[67] The vast ethnic majority in China is named as Han.

[68] A caravan paths network passing through mountainous areas among Sichuan, Yunnan and Tibet, as well as South Asia.

a long and narrow strip shape of the territory, and long coastlines extending for 1650 km from north to south. Vietnam is still a traditional agricultural country with the urban population accounting for nearly 27.2% of the national population (ADB, 2018). But it owns rich tourism resources, with eight sites of the world heritage[69], and the service industry maintains rapid growth in recent years[70].

The specific study area of this research is clarified in the chapter one, and this chapter introduces the geographic situation covering the whole Yunnan and North Vietnam. Figure 43 explains the global location of Yunnan and North Vietnam and a general situation of the distribution of transportation systems and natural resources in the Southeast Asia. Obviously, this area owns rich resources, convenient traffic conditions, as well as an important ecological position. The following subchapters introduce the climate, land relief, hydrology, ecology, soil, land and touristic resource of the Yunnan and North Vietnam as the territorial background of this study. Their relationship with CFY will also be analyzed.

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[69] Central Sector of the Imperial Citadel of Thang Long, Citadel of the Ho Dynasty, Complex of Hue Monuments, Hoi An Ancient Town, My Son Sanctuary, Ha Long Bay, Phong Nha-Ke Bang National Park, and Trang AN Landscape Complex.

[70] The GDP growth rate in 2019 is 7.02% in Vietnam, while in China it is 6.11%, which are both in the process of industrialization.
Data from https://www.kylc.com/stats/global/yearly/g_gdp_growth/2019.html

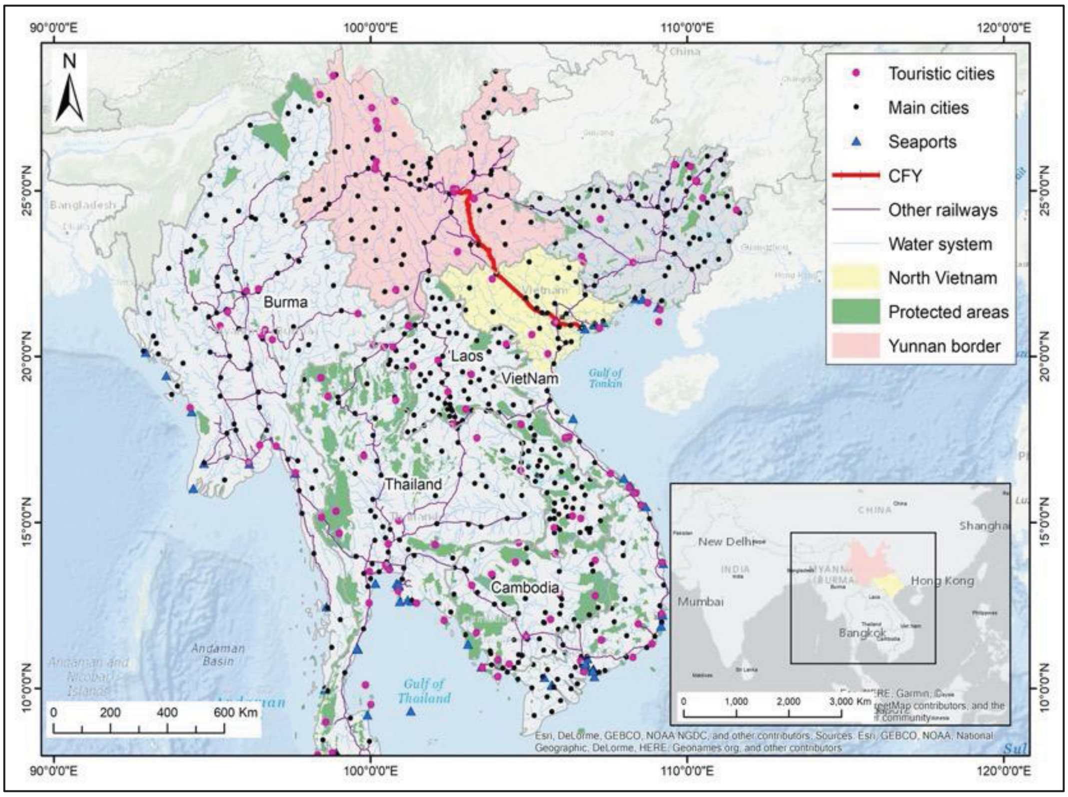

Figure 43, Location of Yunnan and North Vietnam in Southeast Asia

2.1.1 Climatic condition

Under the influences of the East and the South Asian monsoons, plus with the rising of Tibetan Plateau, Yunnan has complex climatic conditions and diversified climatic zones. The climate varies based upon different latitude and altitude, forming three-dimensional characters in the mountainous area. In Yunnan, about 78% of its territory belongs to subtropical zone. Its northwestern area has a strong character of temperate highland climate, with long days with snow cover. The southernmost zone has some tropical characteristics, while the central and eastern Yunnan is characterized by mild winters and tempered summers, suitable for urban and agricultural activities (Duan et al., 2011).

In general, in winter, the province is under the control of continental tropical air mass, making the average temperature in January higher than 6 °C. In summer, the marine air masses make it hot and humid, with monthly high temperature varying from 19 to 22°C. The annual temperature difference in Yunnan is only 10-12°C, but the daily difference can be up to 12-20°C during the winter and spring. The average annual rainfall in Yunnan ranges from 600 to 2300 mm. The seasonal and geographical distribution of precipitation is extremely uneven, decreasing from southeast to northwest. The rainy seasons are from June to August, accounting for about 60% of the annual precipitation. In contrast, the dry seasons are from November to April, with only 10-20% of the whole annual precipitation (PGYP, 2017).

North Vietnam belongs to the humid subtropical climate zone, also under the control of two Asian monsoons, with the temperature in warm month over 22°C, and in cool winter between 18°C and -3°C. The variability of climate is extremely unstable, which brings some natural disasters such as frequent floods and typhoons, influencing more than half of the national territory (Yang & Li, 2003). The dry season extends from November to April. And the monsoon winds make the winter drier in most parts of the country. Snow is seldom seen in the winter. During the period of South Asian monsoon from May to October, the low-pressure system is stabilized, inducing moist air and heavy rainfall to the inland. Especially, the area near Hanoi has distinct four seasons with an annual average rainfall of 1678 mm, an average temperature in June between 25.8- 32.6°C and in January between 13.7- 19.3°C. Its average precipitation in January is 18.6 mm and in June 239.9 mm (HKO, 2018).

Shown in figure 44, the CFY line in Yunnan is mainly crossing the monsoon humid subtropical climate area and temperate highland area. While in North Vietnam, the CFY passes the tropical wet and dry climate in its north and monsoon humid subtropical area in its south. The uncomfortable temperature was one of the reasons that motivated the French colonists to search for another base with more comfortable climatic conditions. But the climate was also a challenge for the railway construction, especially the hot and humid conditions caused a series of diseases, which debilitated the workers and technicians, limited a lot the project progress (Bordes, 2009). Thus, the extreme climate conditions can reflect the hard-working condition in the past, showing also the technological value behind the construction of CFY.

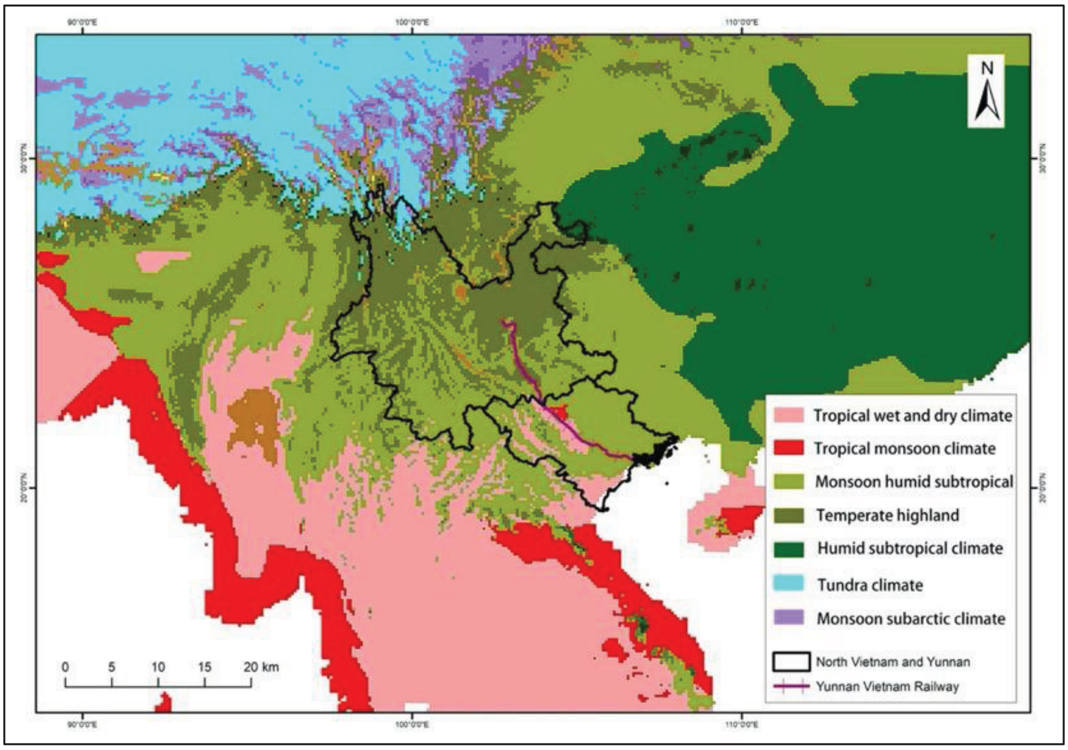

Figure 44, Climatic zone (Köppen-Geiger climate classification)

2.1.2 Land relief

Yunnan is situated in the southern extension of the Tibet Plateau, formed by the collision between the Indian plate and the Eurasian plate. About 84% of its territory is characterized by mountains. The northwest has the highest average elevation and a complex landform. The central eastern part belongs to the Yunnan-Guizhou Plateau, with highlands and mountains higher than 2000 m, connecting with the Hengduan Mountains of western Yunnan. The mountains are higher in the north, ranging from 3000-6000 m, while lower in the south, with an elevation of 1500-2200 m. Most of the land varies greatly, but within a certain range, there are also relatively flat areas, such as basins, valleys, and lakes present between the mountains or on the highlands, called the “Bazi (flatland)” in Yunnan, where there are fertile agricultural areas and densely populated urban districts. About 80% of the Bazi concentrates in the central and eastern Yunnan, among which, Kunming Bazi is the largest one, with developed urban areas gathering there (PGYP, 2017). Due to the mountainous landform, the regional economic growth in Yunnan is exceptionally imbalanced, and the transportation constructions were also hindered in the history.

Vietnam is also a mountainous and forested country. The north and northwest areas are covered by peaks and ridges. The height of the area bordering with China can reach to 1600 m, but the average altitude for the whole country ranges just from 300-700 m. North Vietnam can be divided into three parts: Tonkin deltas (Red River Delta), western mountains, and eastern highlands (NID, 1942). The area near Laos and Cambodian is heavily forested. Due to the erosion process, the mountains are not high in the north compared with Yunnan. Lowlands distribute along the ocean, and rivers extend mainly from northwest to southeast. The Red River Delta is a flat and triangular region intensely developed, densely populated and surrounded by mountains. Nearly 21% of the national population spread in this area, where it is consisted of arable land along the river and valleys. The coastal region is occupied by ancient sand dunes, marine deposits, and alluviums, with many rocky islands near the shore, which brings suitable conditions for agriculture and fishery (GSO, 2016).

Figure 45 shows the variation of land relief in the Yunnan and North Vietnam based on the DEM data (digital elevation model). It is seen that the area in Yunnan is more mountainous than the area in North Vietnam, and the territory where CFY passing through in North Vietnam is mainly plain.

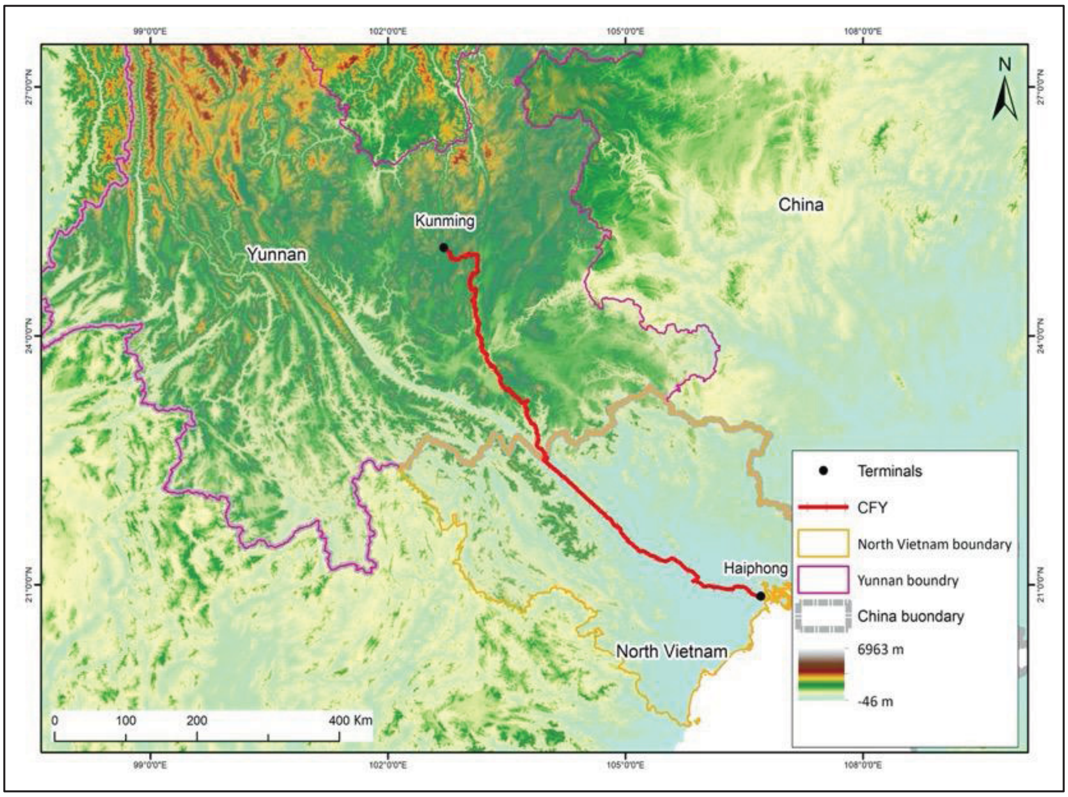

Figure 45, Land relief in Yunnan and North Vietnam

Topographic condition was the greatest difficulty which the engineers met in the process of site selection and railway construction. The technical indicators show that the locomotive type, railway gauge, material, curvature and the design of bridge were all aimed to adapt to the changes of slope and altitude in this area. For example, the steel sleepers were selected for their suitability for the steeper slopes, and the special-structured bridge was designed for the connection between valleys (Namti Bridge).

According to the design regulation of railway line, the slope is one of the most important engineering indexes for the railway construction, which affects the railway engineering quantity and investment of railway project. The difficulty of railway construction is classified into three classes for the railway technology in China: 0.6%, 1.2% and 2% (Liu, 2006). The world's steepest rack railway[71] is the Lisbon Tramways in Portugal with a maximum gradient of 13.8% (Muller, 2020). But in general, a non-rack railway allows the train to operate on steeps with a grade within 9%, such as the famous mountain railways: Semmering railway - 2.5%, Darjeeling railway - 5.55%, and Bernina railway - 7% (Su, 2011). Based on the collected DEM data, further quantitative analysis can be done within GIS to reveal the characteristics of the land surface by the index of slope, to reflect the difficulties of construction in the past and the technological value of CFY.

[71] A rack railway (or cog railway, cogwheel railway) is a railway with a toothed rack rail. The trains are usually fitted with one or more cog wheels, which allows the trains to operate on steep grades.

2.1.3 Hydrography

The river morphology in Yunnan is complicated and shaped like a broom, with nearly 600 rivers flowing basically from its north to south. There are three major river systems in Yunnan: Yangtze River, Salween River and Mekong River, which flow parallelly for some 300 km. This special hydrographical system is known as "Three Parallel Rivers" in the World Heritage List, also as a crucial biodiversity hotspot. Originated from the Tibet Plateau, the Mekong River enters the South China Sea in Vietnam, the Salween River crosses Myanmar and finally enters the Indian Ocean. And the Yangtze River extends eastwardly into the East China Sea. But the navigation conditions of these rivers are not good. The whole province has about 30 lakes, among which Dian Lake and Er Lake are the biggest two, located separately in the Kunming Basin and the Dali Basin. The core urban areas have been formed within these two flat areas in the central and western Yunnan, with the longest history and the highest degree of urbanization. They are also the regional economic, political and cultural centers in Yunnan.

According to the classification of drainage basin, the study area mainly belongs to the basin of Red River[72] (figure 46), which is another international river between China and Vietnam. The river also has its source in western Yunnan and flows southeastwards into the territory of Vietnam. It passes Hanoi, and finally entering the Gulf of Tonkin. It has a length of 1,149 km, with an elevation difference of 2510 m from north to south, and a drainage area of 38,168 km^2. The whole river has a strip shape, with steep slopes, high sediment loads and many short tributaries (Xie, 2002), which used to be an important commercial route between China and Vietnam before the opening of CFY.

[72] Also named Hong river in China, Sông Cái in Vietnamese.

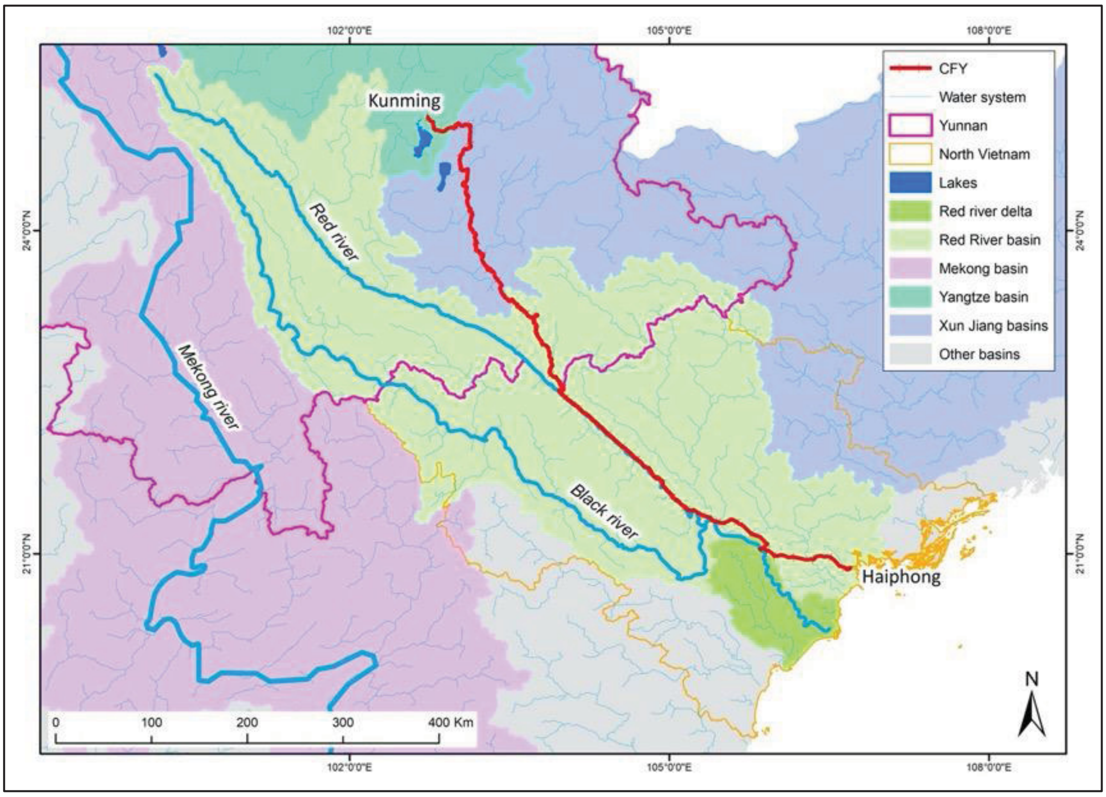

Figure 46, Hydrography and river system

In the case of heritage tourism, steams are one of the objects of visual aesthetics, such as the "Three Parallel Rivers" as a natural heritage site, containing eight core scenic areas, more than 60 scenic spots, with a total area of more than 3,500 square kilometers. Along the CFY, rivers and streams also attract the attention of visitors. In figure 47, the river provides a different color from the green background, and sound of running water is another attractiveness along the railway journey.

On the other hand, during site selection of railway, the hydrological factors need to be considered, such as flood and riverbed, and the shape of water system also restricted the railway project. In order to reduce the work quantities, many sections of the railway were designed to follow the direction of river flow. After construction, the railway also suffered the flood damages during the rainy season, some bridges and culverts had been damaged many times and then repaired. Even nowadays, when the rainy season comes in summer, the operation schedule will be canceled or changed according to the precipitation. Thus, in this study, the river system in the study area is regarded as an index for reflecting not only the landscape quality of heritage tourism, but also the engineering value of railway heritage.

Figure 47, River landscape along the CFY in Yiliang

2.1.4 Ecology and biodiversity

The topographic, hydrographic and climatic conditions discussed above provide various natural habitats in this area, which makes Yunnan and Vietnam two of the areas with the highest richness of biodiversity in Southeast Asia (Yang et al., 2004). Yunnan owns two international hotspots and more than 30 types of ecosystems distributed from the tropical valleys and basin in the south to the high mountains and deep valleys in the north. The terrestrial ecosystems in Yunnan cover almost all types of ecosystems on the Earth, including subtropical evergreen forest, subalpine conifer forest, broadleaf and mixed forests, monsoon rainforest, bamboo forest, dry forest, alpine shrubland and meadows, freshwater swamp, alpine wetland, etc. (Li, 1994; Yang et al., 2004). Besides, it has many living fossils, unique species, and ancient species. There are 180 endemic genera of angiosperm of China in Yunnan, among which about 20 genera are exclusive in Yunnan, such as *Manglietiastrum sinicum* and *Pinus squamaia* (Jing & Zhang, 2006; YEPH, 2017). As a result, Yunnan earns its reputation as a kingdom of unique plants and animals in the world.

Vietnam is one of the countries with the richest biodiversity and agro-biodiversity in the world. It is included within the Indo-Burma Biodiversity Hotspot with a wide range of natural environments, from terrestrial ecosystems and wetland ecosystems to marine ecosystems, such as tropical forests, pine forests, mangroves, streams, lagoons and coral reefs, which provides various ecosystem services to its people. There are in all 14 terrestrial ecoregions recognized by WWF, and about 10% of its local plant species are endemic, owning 10% - 16% of the world's species (De Queiroz, et al., 2013).

As is shown in figure 48, the Yunnan and North Vietnam have a similar ecological condition. They have the same biome type, namely the tropical/subtropical moist broadleaf. Then, for the forest type, the Northern Indochina subtropical forest and

Yunnan Plateau subtropical evergreen forest account for the most of this area. The ecological importance of Yunnan and North Vietnam is classified into the third and fourth class[73], compared with other regions in South East Asia. Then, figure 49 displays the important ecoregions including the ecological corridors, key biodiversity areas (KBA) and protected areas in Yunnan and North Vietnam, which are recognized by the IUCN.

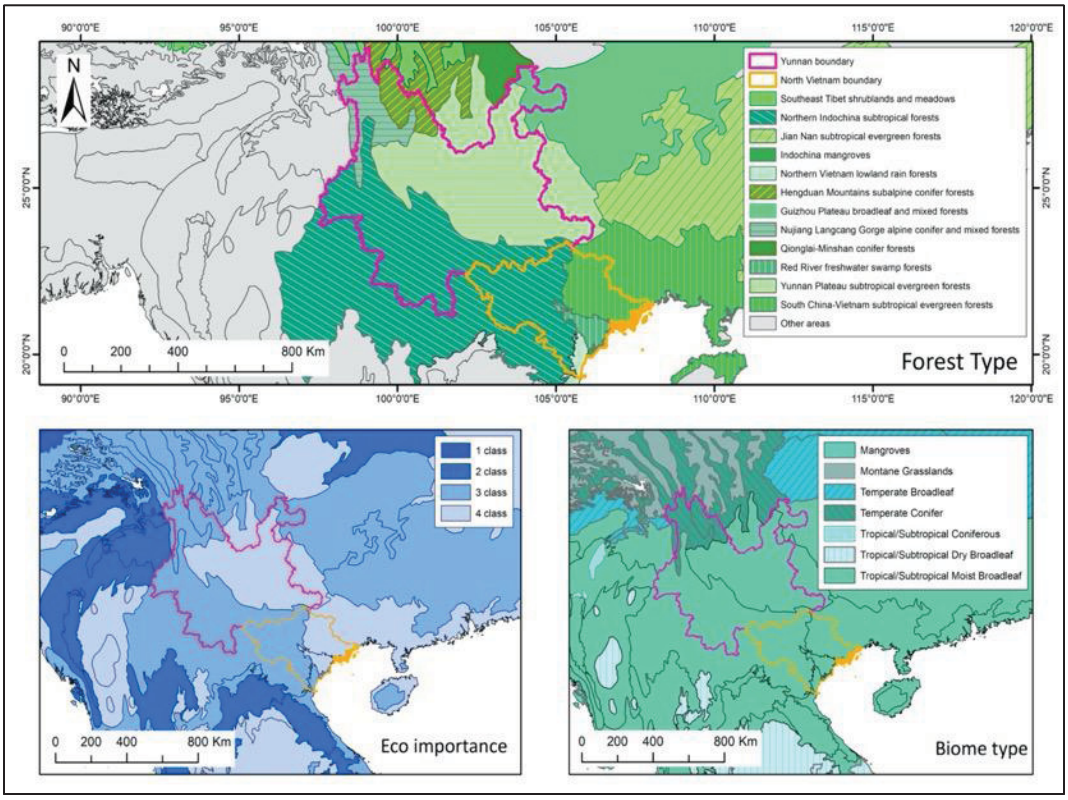

Figure 48, Ecological importance of Yunnan and North Vietnam

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[73] Order of importance: 1st > 2nd > 3th > 4th.

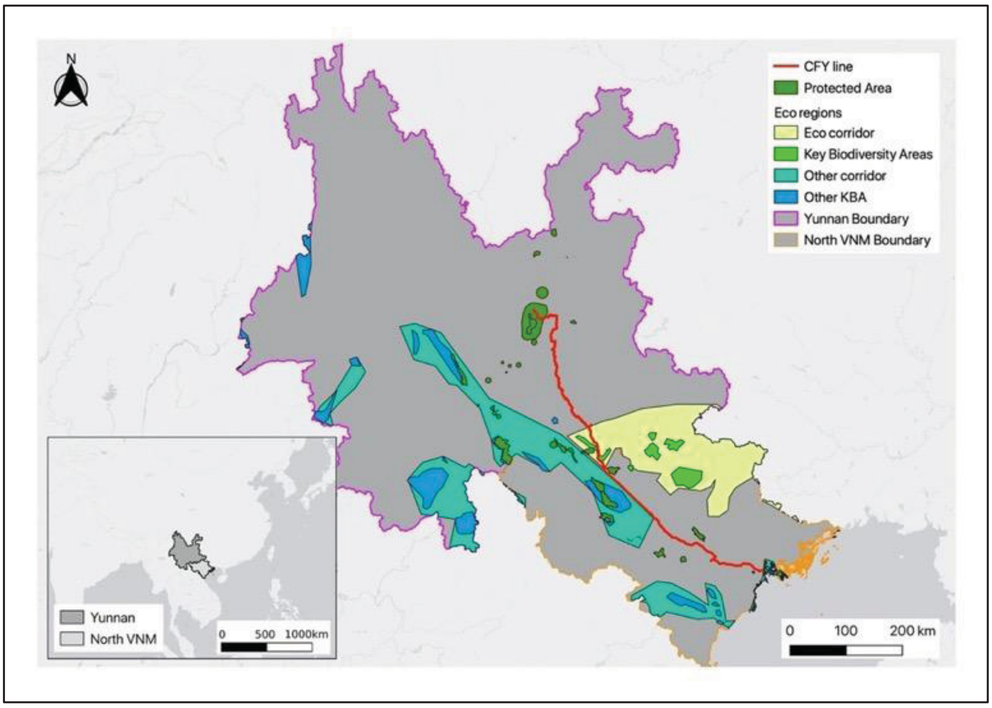

Figure 49, Eco-regions in Yunnan and North Vietnam

For touristic activities in the study area, ecology and tourism interact with each other. Ecosystems bring various benefits for human beings, which means a lot for our daily life and tourism for their values in education, spirit, recreation, and aesthetics (Daily, 2003). The natural environments, such as forests, coastlines, mountains, rivers, animals, and their natural habitats, are important attractions for tourists. A place with a higher ecological value can be regarded as national parks or protected areas, which will also be a popular nature-based touristic destination. But during the tourism activities, the travelers can bring some negative effects for the ecosystem, such as invasive species, illegal collections, animal feeding and so on.

Thus, during the heritage developing activities, especially a heritage system like CFY, where the natural environment is closely related to human activities and tourism relies heavily on the protection of ecosystems, it needs to be fully aware of the relationship between ecology and tourism (Nyaupane et al., 2011). In this research, the ecosystem is also taken into consideration as a part of the CFY heritage corridor, and the ecological meaning of this area is also a part of the heritage value of CFY.

2.1.5 Soil and land

Soil is one of the basic environmental factors, and its quality has important effects on human lives, habitats and ecosystem functions. As an indispensable natural resource, soil can provide fertility for green vegetation, and assimilate the pollutants in it. Besides, the soil type, texture, structure, nutrients, pH value and density are all connected with its quality, influencing the health of vegetation and crops. At the same time, soil is also a fundamental factor in many landscape and environmental projects (Lee, 2017).

Soil erosion influences the condition of natural and cultural heritage sites, as a common problem for south-east Asian countries. Soil erosion, soil productivity, and food security are factors concerned in the mountainous area in Asia (Yang & Liang, 2004). In Vietnam, 75% area is covered by slopping land, among which 50% of the slopes are more than 20°. The six types of predominant soils in Vietnam are grey degraded soil, yellowish and reddish humic soil, yellowish and reddish soil, young alluvial soil, acid sulfate soil and saline soil (Bui, 1995) and in northern Vietnam, the most common soil is the reddish one. In the Red River Delta, the fertile alluvial soils are suitable for intensive agricultural activities. With the growing pressure of population, the conflicts between forest conservation and cultivation are deepening, so Vietnam is also suffering from deforestation and other soil problems, especially the northwest Vietnam (Lam et al., 2005; Clemens et al., 2010).

In Yunnan, the northwest and west regions are manly covered by conifer forests, subtropical mixed deciduous-evergreen, broad-leaved forests, and subtropical conifer forests. A higher organic matter content and fine soil structure are typical in these areas. At the same time the southwest region is characterized by latosols, latasolic red soil, and red soil[74]. Central and southeast regions are dominated by red earth,

[74] The classification system of soil is made by the Food and Agriculture Organization (FAO). Explanation of each abbreviation in the map: Af- *Ferric Acrisols*, Ag- *Gleyic acrisols*, Ao- *Orthic*

limestone soils, and purplish soils. In the northeast region of Yunnan, the soil productivity is relatively lower than northwest and west mountainous region, but higher than the southwest, central, and southeast part (Duan et al., 2005).

The area where CFY is passing through has the soil mainly belonged to ferric acrisols in Yunnan, orthic acrisols in North Vietnam, and eutric gleysols in the Red river delta (figure 50). According to the description of FAO, the acrisols in general is natured by a humid tropical environment, which related to the woodlands. But these soils are with a lower level of nutrients and a higher erodibility. Then, the gleysols are closely related to groundwater, which is characterized by the depletion of oxygen in the soil caused by the saturation of water, being suitable for arable activities.

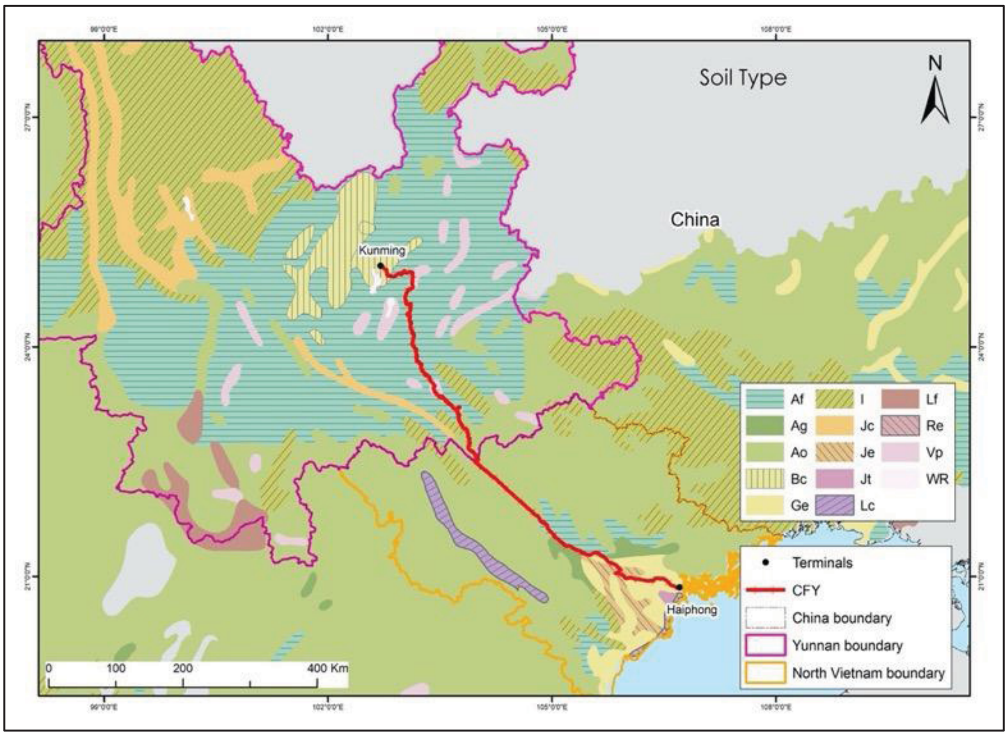

Figure 50, Soil type and soil classification

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acrisols, Bc- *Chromic Cambisols*, Ge- *Eutric Cambisols*, I- *Lithosols*, Jc- *Calcaric Fluvisols*, Je- *Eutric Fluvisols*, Jt- *Thionic Fluvisols*, Lc- *Chromic Luvisols*, Lf- *Ferric* Luvisols, Re- *Eutric Regosols*, Vp- *Pellic Vertisols*, Wr- water erosion.

Besides, land use/land cover (LULC) data is also collected in this study since the land cover change is important in both natural and cultural applications, such as monitoring the climate and environmental changes, disasters like flooding, fire and landslide, as well as regional development, heritage protection and touristic activities. A heritage site closely interacts with the land and its surrounding, such as the soil erosion, weathering phenomena and change of land condition by human activities, directly influencing the sustainable development and management of cultural heritage.

In order to gain the near real-time data for the land, the remote sensing data need to be acquired. The land cover data is shown in figure 51, the current land cover comparing with the historical land use can reflect the land use/cover changing in the history. Such analysis of historical land use change will be helpful for providing insights into the cultural landscapes, the decision-making of future land management, the implementation of land conservation measures, as well as the redevelopment of CFY heritages. The LULC data are also useful for analyzing the land suitability for developing touristic activities in the protective areas of heritage.

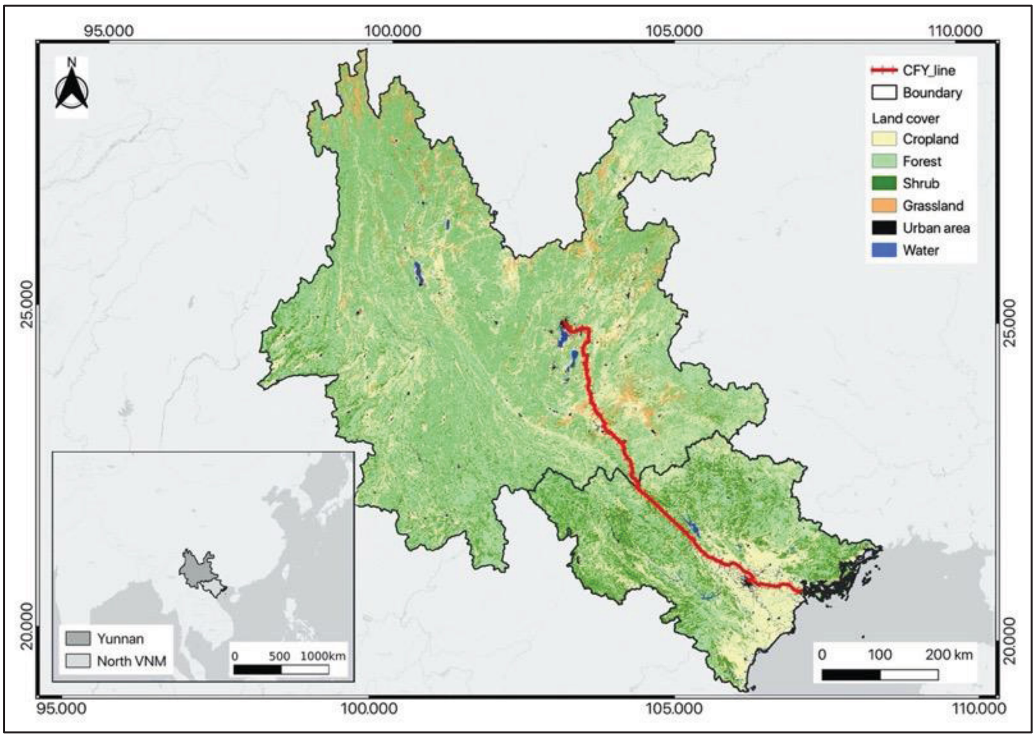

Figure 51, Land cover in Yunnan and North Vietnam (2015)

2.1.6 Touristic resources

Yunnan and Vietnam are both popular destinations for international tourists. The tourism resources in Yunnan are distinctive for all the natural geographical conditions manifested in this chapter. These environmental factors provide both natural and humanistic tourism resources, with diverse types of sceneries with high landscape quality. Besides, a long period of cultural and historical development has also brought abundant cultural relics, as well as the diversity and uniqueness of the coexistence of ethnic groups in this region. The integration of special geological landscape and ethnic culture gives Yunnan a great value of tourism (Wang & Zhao, 2002).

Currently, Yunnan owns 232 A-level touristic attractions[75], including eight 5-A class tourist attractions and 68 sites of 4-A class tourist attractions. The number of 4A touristic attractions accounts for 32.7% of the whole number of A-level touristic attractions. Yunnan also has three national touristic resorts, three national eco-tourism demonstration zones; 38 national and provincial touristic towns, and 350 provincial touristic villages. The development of the tourism industry has been continued to accelerate these years, and the number of tourist attractions with national and international popularity has continued to increase. According to the statistic, the regions of CFY (Kunming, Yuxi and Honghe) possess 35% of the whole heritage resources in the province, which are also the most popular tourist destinations in the whole province (Cao, 2015).

[75] Chinese classification of scenic areas includes five classes from AAAAA (5A) – A (1A), which indicates the quality of these sites. 5A and 4A are regarded as the scenic spots with best landscape quality in China. The 5A heritage classification involves only the cultural and natural heritage sites. Then, the Vietnamese heritage sites in figure 50 include all the tangible and intangible cultural heritages recognized by the Vietnamese government. Thus, the heritage number shown in figure 50 is with a big difference.

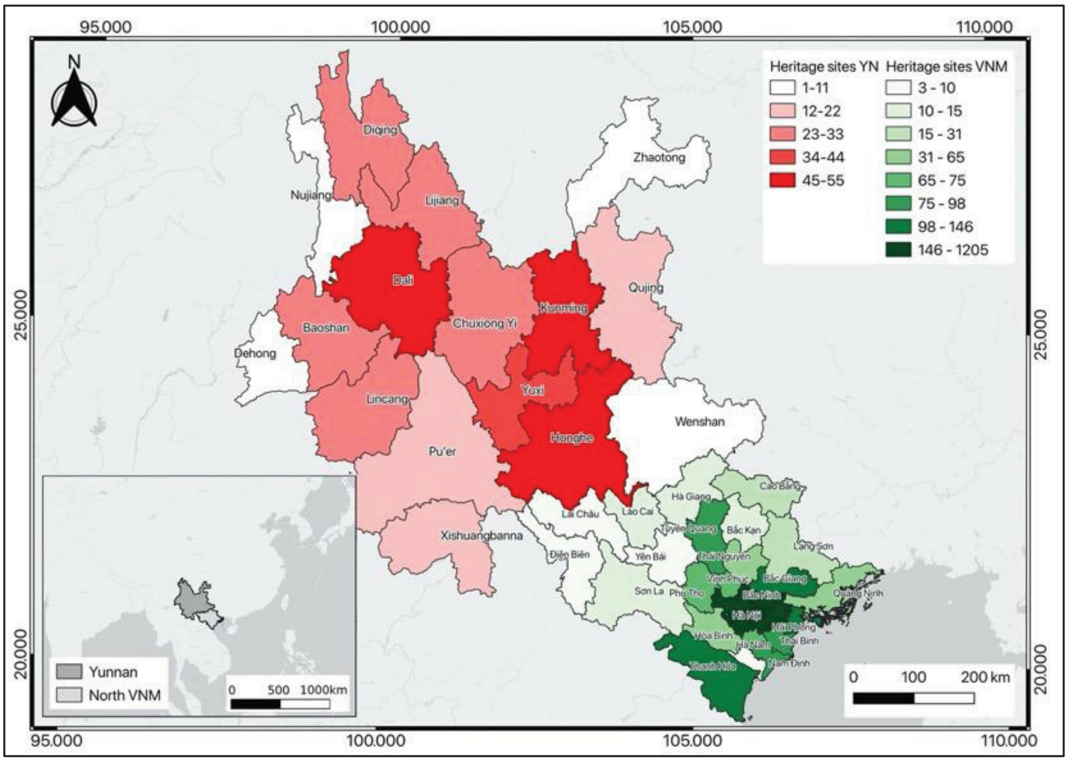

Figure 52, Cultural heritage in Yunnan and North Vietnam

Vietnam is also rich in tourism resources, and the tourism industry plays an active role in promoting the development of Vietnamese economy. Expects estimated that Vietnam could receive approximately 20 million tourists in 2020, and the capital Hanoi is the most popular tourist destination in Vietnam[76]. There are eight UNESCO sites in Vietnam, among which four sites are located in the North of Vietnam. Vietnam's major tourism resources include cultural and historical relics, archeological relics, revolutionary historical relics, natural landscape relics, architectural art relics. The country has acknowledged nearly 40,000 sites of cultural heritage, which can be divided into five classes: special-national, national, provincial, and local level.

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[76] Website: https://www.vietnam-briefing.com/news/vietnams-tourism-sector-opportunities-investors-2020.html/

According to the statistic of Cao (2015), a map of the distribution of Vietnamese cultural heritage is made to represent its touristic resources together with Yunnan province (figure 52). It reflects that the provinces with the highest density of cultural heritage in Vietnam are Haiduong, Hanoi and Bacninh, which are all the areas crossed by the CFY. Then, the touristic footprints on Flickr (touristic photos taken in Yunnan and North Vietnam from 2003 - 2014) are also collected to reflect the tourist density in this area. The tool of Kernel Density Estimation in QGIS is used to calculate the footprints density. The result map (figure 53) indicates that the sites in Yunnan attract most visitors are the areas near Dali, Lijiang and Diqing (Northwest of Yunnan), and along the CFY, the most popular sites are near Kunming, Laocai and Hanoi. Further quantitative analysis of comparing the popularity of these sites will be done in the next chapter.

Although not all the touristic resources are related to the CFY history or associated with the railway heritages, they can be regarded as the potential value for the touristic development of the regions along the CFY. Thus, different types of touristic resources are also be included in the CFY heritage corridor system.

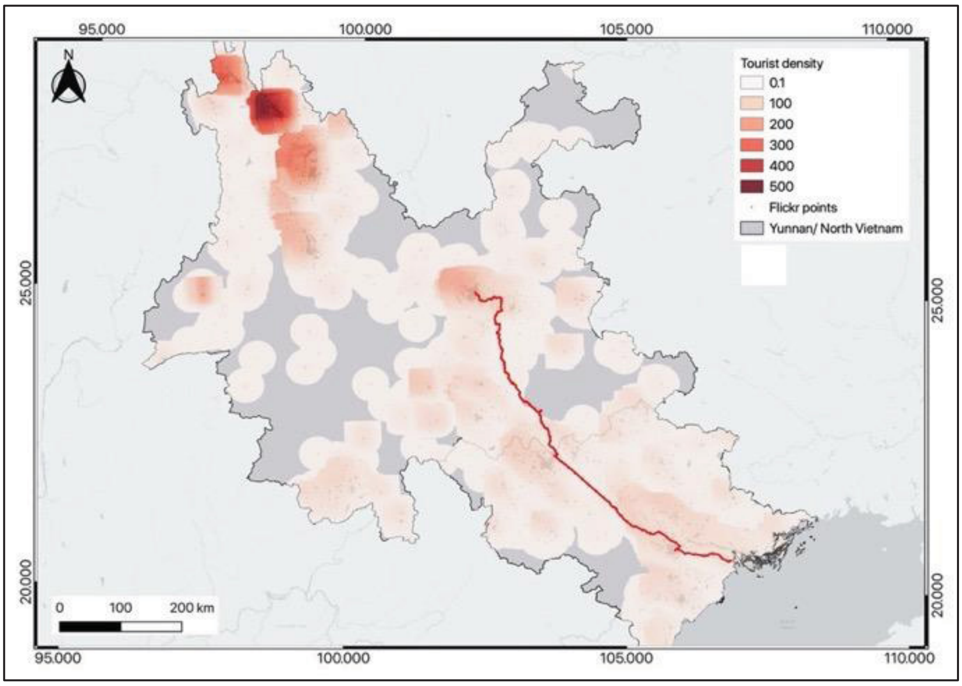

Figure 53, Tourist density in Yunnan and North Vietnam

2.2 Historical context

2.2.1 Colonization of Vietnam

In the history, Vietnam was dominated by China for nearly one thousand years[77], having a close relation with Yunnan, and under profound influence of Chinese culture. Being a vassal state of China from the 10th century, Vietnam started the process of external expansion in the Indochinese Peninsula[78], tried to conquer Laos and Cambodia. At that time, in Europe, after the failure in a series of wars, France lost many of its overseas colonies in the early 19th century[79]. The Second French Colonial Empire during 1808-1873, aimed for the renewal of France, began to extend its colonial territory in Asia, also rivaling with British power in this area. On the contrast, the countries in Southeast Asia were still economically backward. Until 1830, a tribute system was successfully built for the formation of the Indochinese hegemony under the control of Vietnam (Li, 2004).

The Dutch and the Portuguese firstly penetrated this area in the early 17th century. Then, the religious preachers, explorations, and commercial activities enhanced the early relations between France and Southeast Asia. Especially, Alexander de Rhodes[80] made a significant contribution to the dissemination of Catholicism in Vietnam and the Latinization of the Vietnamese language. In 1787, the Versailles Treaty between France and Vietnam confirmed the privileges of French merchants in Vietnam. However, during the 18th century, there was an increasing prejudice against the

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[77] From Han dynasty to Tang dynasty (2nd century BC – 9th century)

[78] Historical term, referred to Myanmar, Thailand, Laos, Cambodia, Vietnam and Singapore. In this article it intends the countries under the control of France in 18th and 19th centuries, namely Laos, Cambodia and Vietnam.

[79] The loss of the colonies in India and North America during 1744-1815.

[80] A French Jesuit missionary (1591-1660).

European merchants, even the Vietnamese emperors intended to resist the French infiltration since 19th century, trying to restore the traditional civilization. Some French missionaries were killed during that time, which became the fuse of wars (Cotterell, 1906; Llewellyn et al., 2016).

In 1858, the joint navy of France and Spain attacked Saigon. In 1862, the Treaty of Saigon was signed, and Southern Vietnam, including three provinces, were ceded. In 1863, France invaded Cambodia and forced it to be a French protectorate. In 1867, three more southern provinces were occupied: Ha Tien, Chou Doc and Vinh Long, and this area was named as the Cochinchina[81] (NID, 1943). But comparing with Cochinchina, The North Vietnam had a strategic importance for building a passage to enter the southwestern China, where it owned abundant resources of forests, rivers, arable lands and labor forces (Shao, 1935; Liu, 2017). Since the explorations in Yunnan and Indochina in the 19th century, France started to invade the North Vietnam and utilize the Red River as a commercial corridor to get access to Yunnan. After the Franco-Prussian War (1870-1871), the president Jules Ferry[82] began to speed up the colonial affairs in Vietnam, solving the conflicts with China.

In 1874, in the Second Treaty of Saigon, France recognized Vietnam as a country free from the Chinese tributary system. It also acknowledged the sovereignty of France over Cochinchina. However, due to the ambiguous description in the treaty, the sovereignty of Vietnam was interpreted differently by France, China, and Vietnam, which stimulated potential contradictions. In 1883, the Sino-French War broke out, in 1885, the Treaty of Tientsin was signed. French took over the whole of Vietnam, and China totally lost its suzerainty over Vietnam. Since then, the basic shape of French Indochina had been formed together with Cambodia and Cochinchina. Vietnam was divided into three regions: the north as Tonkin, the middle as Annam and the south as Cochinchina. Then, the territory of Laos was acquired in 1893 after the treaties and

[81] Literally, it means the Land on the south.

[82] 1832-1893, as the president during 1880–1881and 1883–1885.

agreements with Siam (Thailand), as well as the lease of Kwangchowan[83] for 99 years confirmed in 1899 (figure 54) (Liao, 2002).

Figure 54, Territory of Indochina and its administrative division

During the governing of Paul Doumer[84], a federal union was achieved in Indochina, among which only the Cochinchina was a total colony but other parts as the protectorates. Under the centralized authorization by Governor-General, the five provinces (Cochinchina, Annam, Tonkin, Laos, and Cambodia) were governed in different ways and statuses. Only Cochinchina was directly ruled by the governor from Saigon[85], adopting the French law. Annam, Tonkin, and Cambodia were

[83] Currently names as Zhanjiang city in China.

[84] The governor-general of French Indochina from 1897 to 1902.

[85] Current Ho Chi Minh City.

governed by local Chief Residents. Their original kings and governmental officials were nominally remained, but the entire administrative system was totally limited by the colonial authority, who actually controlled the national defense, diplomacy, customs, and finance of Indochina (Cooper, 2001). During the WWII, Japan took complete control of this area and destroyed the French colonial system in Indochina. In 1954, the governing by France in Indochina was finally terminated. So far, the history of Indochina was over, and the Vietnam was split into North and South until 1976.

Till now, there are plenty of academic works focusing on the history of French Indochina, from the discussion of the general history of this area (Thompson, 1937), to the detail of some specific aspects of the colony, such as the colonial education and economics (Clayton, 1995), social consciousness changes under the colonialism (Marr, 1981), the failure of colonial policy (Burlette, 2007), the anti-colonial activities (Duong, 1985), etc. Though the colonial government tried to improve the infrastructures in Indochina from the improvement of agriculture, transportation, health care, education and communication, those interventions destroyed the local tradition and brought drastic changes in the local culture, and finally led to the uprisings against the colonists.

2.2.2 European explorations in Yunnan

The French and British interests in Southeast Asia, especially their commercial competition in Siam and Burma[86], were started in the early 17th century. After the period when Britain occupied India and Burma, France successfully built its colony - French Indochina. The colonial power gradually extended to China, achieved by a series of military interventions and unequal treaties. After the Second Opium War[87], the Treaty of Tientsin[88] and the Convention of Peking[89] were signed by the Qing government. In this way, foreigners could travel freely in China, whose commercial and missionary activities were also legalized. The early European explorers believed that the shortest route to China was connected by the rivers in Indochina to the Yangtze River (Christian, 1941). In order to find more commercial routes and explore natural resources, an increasing number of exploratory journeys by Europeans were conducted in Yunnan. The enthusiasm of the exploration of Southeast Asia lasted for nearly one century with many explorers participated, consisted of diplomats, officers, businessperson, journalists, scholars, missionaries and so forth. Making business was their primary purpose, along with other fields of research such as geography, geology, biology, and anthropology. Among these, there were more than twenty times of exploration happened in Yunnan province (Yang, 2011).

Doudart de Lagrée[90] and François Garnier[91] were one of the early French explorers in Indochina and China. In 1866, started from Saigon, they traveled along the Mekong River, passing through Cambodia, Thailand, and Laos, then entered in Yunnan in

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[86] The former name of Thailand and Myanmar.

[87] 1856 - 1860 between the UK, France and Qing government.

[88] Signed in Tianjin in 1858.

[89] Signed in Beijing with the Great Britain, France, and Russian Empire in 1860.

[90] 1823-1868, the leader of the French Mekong Expedition.

[91] 1839-1873, A French explorer in Indochina.

1867. They investigated the area of Sichuan and the Yangtze River, finally arrived in Shanghai in 1868. The expedition crossed about 10,000 km, of which nearly 4,000 -km journey was finished on foot. It was considered as one of the most significant scientific expeditions in the 19th century in the world. Their investigation referred to the temperature, latitude and longitude, topography, hydrology, natural and mineral resources, folklore, languages, heritages, local products and commodity prices, etc. A detailed report with the map of the Mekong River Basin was completed and submitted to the colonial government, stating that the Mekong River was not suitable for navigating for its rapids and instead. It was firstly proposed that the Red River between Yunnan and Vietnam can be used as a gateway to reach China (Garnier, 1873; Taboulet, 1970). At almost the same period, during the military trades with the Chinese government, Jean Dupuis passed through Sichuan, Guizhou, and Yunnan, researched the history and ethnic culture in Yunnan. Dupuis also traveled from Indochina to Yunnan, investigated the navigation condition of the Red River for the first time, which proved the feasibility of this commercial channel as the connection between Indochina and Yunnan.

In 1881, A.S. Colquhoun took his expedition from southern China to Burma. Later, he published a series of reports of his journey in Yunnan. He described Yunnan as the wealthiest province with abundant mineral resources in the south of China, which would be a vast potential market for Britain (Colquhoun, 1882). Though there were some exaggerations and misunderstandings of the topography and population in Yunnan, his description caught further commercial curiosity of Yunnan in Britain, and Yunnan was regarded as a myth land for trading by foreigners. The journey of Captain Ryder also proved the abundant mineral wealth, including gold, silver, lead, tin, iron, copper, zinc, coal and so on (Davies et al., 1903). On the contrast, in 1885, F. S. A. Bourne started his journey in southwestern China to survey the financial and traffic conditions. He reported the difficulty of developing railway system because of the mountainous territory and the poverty in this area. The similar statements were also reflected in Britain from the reports by A. Hosie and E. C. Barber, they doubted that trading with Yunnan was not optimistic, and the trades with Yunnan would have limited profits (Walsh, 1943).

Table 7 shows the different kinds of foreign explorations in Yunnan in the 19th and 20th centuries, mainly by the UK, France, and the USA. There were also many other exploring activities happened in Yunnan during that period.

Table 7, Foreign explorations in Yunnan in the 19th and 20th centuries

Compared with the British expectations in Yunnan, France took more effective and positive measurements in Yunnan, based on its geographic advantages from Indochina, such as opening trade customs, shipping on the Red River and the constructing of Yunnan-Vietnam Railway. After the Sino-French War, the strategical and economic position of Yunnan had improved a lot. During the past cross-border trades, the frontier cities in Guangxi and Guangdong were the principal routes for economic exchanges with Vietnam. As Mengzi in Yunnan setting as the customs (figure 55), the commercial trades between Yunnan and Indochina began to exceed those in other provinces. The imports of goods to Yunnan increased 7.5 times within one year in 1889, and within ten years there was an increase of 107 times. Later, the other two customs were added in Yunnan, namely Tengyue and Simao[92], but the foreign trades through Mengzi far exceeded those from the other two. In 1910, the opening of Yunnan-Vietnam Railway had witnessed the period of economic flourishing of cross-border trading in this area (Wei, 2008).

[92] In the west and south west of Yunnan.

Figure 55, Mengzi customs

2.2.3 Railway construction in Indochina and Yunnan

Since the exploration led by François Garnier from the 1870s, there were plenty of geological and geographical surveys by French in Yunnan and Indochina, which laid the foundation for further constructions and penetration in China. The local chronicles of Yunnan, Kunming, and Honghe recorded the history of the construction of CFY. In 1885, the Treaty of Tientsin allowed France to trade in Yunnan and Guangxi, stated that the boundary between China and Tonkin would be defined again in accordance with France. The seventh article prescribes, “if China would like to build any railway, it needs to be negotiated with France”. In this way, France obtained the rights of setting customs, tax reduction and building of transport infrastructures in China. In the supplementary treaties in 1887, France seized parts of the territory of Yunnan, the right of mining, and further claimed that the railway in Indochina could be extended into Yunnan.

From 1895 to 1897, several French chambers of commerce conducted large-scale exploratory activities in Indochina and southwest China, aimed for making the connections between Indochina and China and examining the commercial value of Southwest China. In their report, it concluded that Yunnan was rich in mineral reserves, the tobacco industry was one of the primary economic sources in Yunnan. There were great opportunities for trading opium, medicinal herbs, musk and tea and other local specialties. They also suggested building a railway in Yunnan for transporting mineral resources (CCI, 1898). Before the construction of CFY, the transportation through Red River was the primary commercial route between Yunnan and Indochina. However, the Red River flows turbulently with obstructions in the course, which allowed only the small vessels to pass through from November to March. The limited carrying capacity could not meet the needs of transportation for the French expansion to southwestern China.

In the process of construction of traffic infrastructure in Indochina and Yunnan, it was the general governor Paul Doumer who played a central role. As one of the most powerful governors of Indochina, he placed the economic development in a significant position. According to the report of CCI and the proposal by Marquis de Mores[93], Doumer suggested comprehensive measurements for developing Indochina from the aspects of agriculture, commerce, forest industry, military, education, sanitation, communication and so on. The railway network was projected of high priority to connect the three sections of Vietnamese territory with China, to link the Delta of Mekong and Red River Valley, Yunnan, Cambodia, and Siam (Doumer, 1902). In 1898, the supreme council of the Indochina approved the plan of this 3200 km railway system. After the Siege of the International Legations in 1900, France received massive indemnity from China as one of the funds guarantees for the construction of the railway. In 1903, France and China signed the Chart of Indochina-Yunnan Railway (figure 56)[94], which officially allowed to build the railroad from Laocai (Hekou) to Kunming and France would control the total rights of construction and management of this railway.

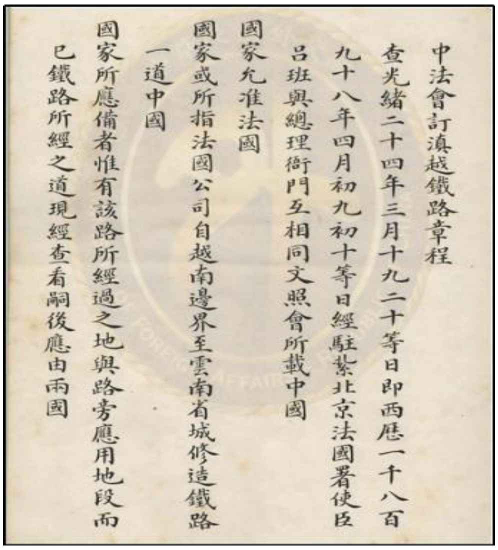
中法會訂滇越鐵路章程
查光緒二十四年三月十九二十等日即西歷一千八百
九十八年四月初九初十等日經駐紮北京法國署使臣
呂班與總理衙門互相同文照會所載中國
國家允准法國
國家或所指法國公司自越南邊界至雲南省城修造鐵路
一道中國
國家所應備者惟有該路所經過之地與路旁應用地段而
已鐵路所經之道現經查看嗣後應由兩國

Figure 56, The first page of the Chart of Indochina- Yunnan Railway

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[93] French political activist, he firstly proposed the plan of building a railway between Yunnan and Vietnam.

[94] It states that the Guangxu Emperor permitted the construction of the railway by France from Vietnam to Yunnan.

After the constitution of "Compagnie française des chemins de fer de l'Indochine et du Yunnan" in Paris, and an office in Mengzi, eleven times of investigations for rail-line selection had been finished. Théophile Pennequin was responsible for the first survey of site selection. It was described that the section between Mengzi and Laocai is located in the tropical area, with rapid flows, epidemics, and sparse population, in comparison, from Mengzi to Kunming, this section has a mild climate, with various resources, convenient traffic conditions and large population (Zhang, 1942). The original line was chosen along Hekou- Mengzi- Kunming, with a project budget of 70 million francs[95]. However, because of the steepness of the terrain, the difficulty of technique and the occupation of fertile arable lands, this plan was not approved. At the same time another plan by M. Yuiliere that proposed a line from Hekou- Kaiyuan- Yiliang- Kunming, was officially adopted in 1904.

The construction has proceeded since 1901[96]. It took six years and three months till January of 1910, the rail was finished in Yunnan, and in March it was put into operation (Zhuo & Zhu, 2001). The section from Haiphong- Hanoi - Laocai was completed in 1905. Other sections of railway system in Annam and Cochinchina were also completed until 1912. Then, from 1927- 1936, the north, central and southern sections were linked together. The coastal route runs from Hanoi to Vinh, Hue, Saigon, Mytho, and Cantho, also called the North-South railway of Vietnam (Transindochinois)[97], which has a total length of 2,524 km, and functions well nowadays (figure 57).

Beside of railway system, French contributions in Indochina can be reflected in other economic aspects, including agriculture, communication, urbanization and industries, for example, canals in Mekong plain; port of Saigon; urban planning and architectural

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[95] French franc was a currency of France from 1795 - 2002.

[96] The Vietnamese section started from 1901 and the parts in Yunnan started in 1903.

[97] The North–South railway from Hanoi to Saigon, which is still functioned as the main railway framework in Vietnam.

heritages and other public services. During the colonial reigns, the core strategy of colonial policy, based on the development situation and economic growth of the former three states, was to establish a political and economic community, in which Hanoi served as the political center, Saigon as the economic center, Cambodia and Laos in a subordinate position. The imperialists claimed that they were under the responsibility to introduce civilization, modernization and industrialization to these undeveloped areas in Asia.

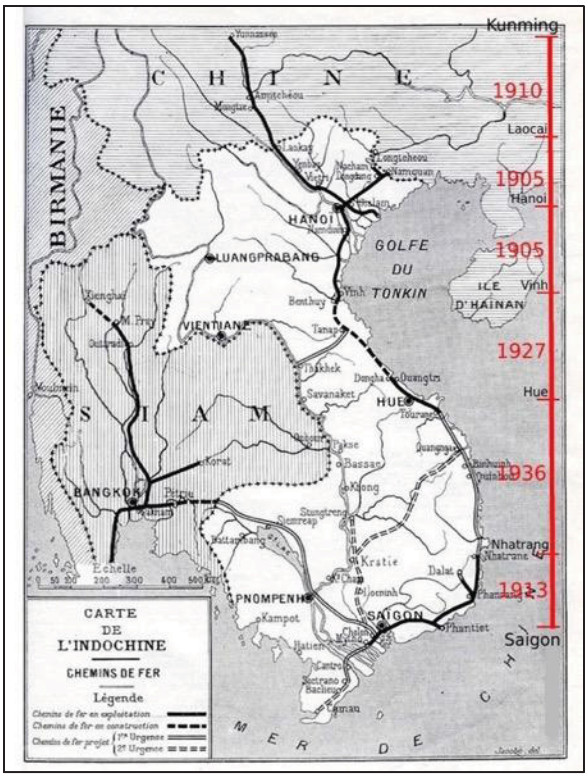

Figure 57, Year of construction of Yunnan-Vietnam Railway and Transindochinois

The ambitious construction plan in Indochina and Yunnan was as one of the illusions of the civilizing transformation and imperialism in the Far East by France, which played an essential role in French economic and political policies (Starostina, 2010). It was also a symbol of the transition of the French colonial policy, shifted from assimilation to association, by cooperative efforts from colonialists and locals including Cambodians, Laotians and Vietnamese (De Testa, 1999). However, Cooper (2000) stated that the planning and construction in the colony were aimed to consolidate and perpetuate French rule in Indochina, their activities were primarily driven by economic interests, for improving the accessibility across the Indochina, reaping profits from the Asian countries and penetrating China further through the railway corridor. They plundered and exploited lands and other resources, imposed heavy taxes and usury, especially, the imbalanced policy failed to create a shared identity, but intensified the opposition and internal conflicts between Vietnam, Cambodia and Laos (Liang, 1999; Li, 2004). Anyway, the construction of CFY and other railways in Vietnam brought advantages, to some extent, outweighed its disadvantages. Especially, it meant a lot for the industrialization of Yunnan and Vietnam.

During the WWII in Asia (Second Sino- Japanese War), CFY was served as the most important route for transporting supplies from other countries to China. It was described as a “lifeline” for Chinese military (Bloch, 1940), as well as a hot issue seeing the relations among China, Indochina and Japan. During 1938 - 1939, the traffic volume of the Yunnan-Vietnam Railway reached its highest peak since its operation. Till 1940, the government of French Indochina was forced to issue the bans on transportation between China and Vietnam. To prevent the Japanese invasion, the section between Hekou – Bisezhai was demolished by China at that time. The military defense ability of the Indochina was proved to be poor, which also gave a signal of the decline of French power in Asia. At the same time, the WWII opened an opportunity for local Vietnamese to fight for their independence and sovereignty (Cam, 2014).

CHAPTER 3. METHODOLOGY

This research defines an interdisciplinary and geo-historical approach, using Historical GIS (HGIS) as the main methodology to construct the railway heritage corridor system for further geo-analysis, evaluation and redevelopment. Other methods are also involved in the process of the creation of heritage corridor and heritage evaluation, including the Delphi expert method, Analytic Hierarchy Process (AHP) and Minimum Cumulative Resistance Model. GIS combines these tools as a spatial integrated method. This chapter clarifies the specific process of the construction of CFY heritage corridor based on HGIS. The methodology carried out is divided in six steps as following: data acquisition from various sources; data classification; vector and raster data preprocessing; data management by GeoPackage; building the heritage corridor; applications based on the built heritage system. The detailed steps are explained in figure 58.

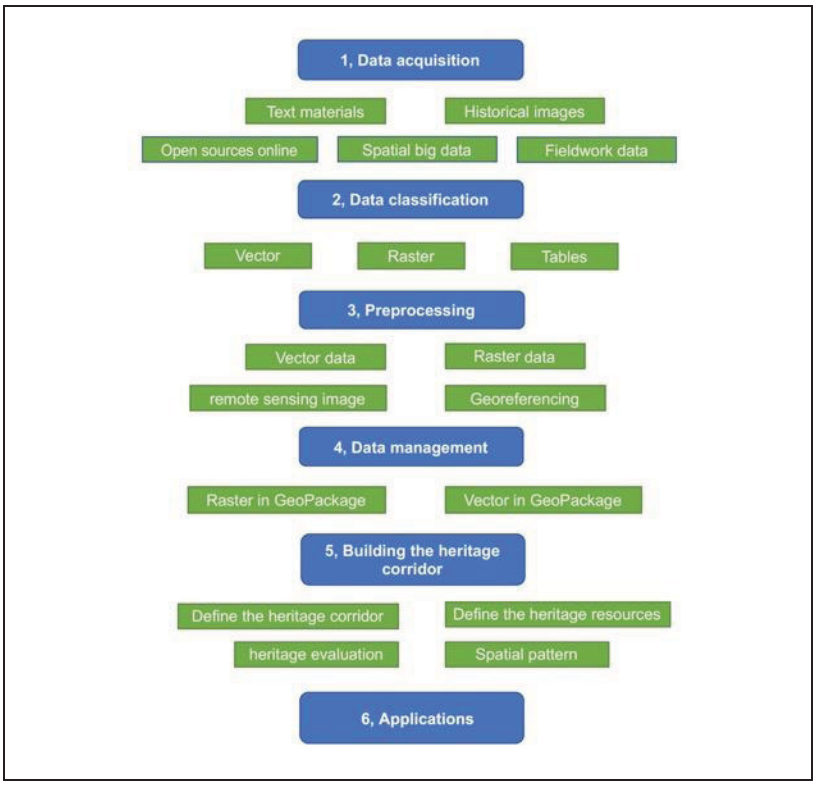

Figure 58, Workflow in the research

3.1 Data acquisition

Data acquisition is the first step in this research as a foundation for preparing a database and performing further spatial analysis. The traditional methods for collecting data include 1) scanning and transferring paper documents into digital environments; 2) the open source spatial data, like shapefile, satellite images, and other data formats; 3) the acquisition of field data through GPS devices or other surveying tools. There is also an emerging trend of applying digital tools for scanning the land for collecting heritage data, for example the unmanned aerial vehicle (UVA) and territorial laser scanning (TLS), which are mainly used to record the architectural heritages. Meanwhile, the big data generated and shared from Internet and social media brought changes to the cultural heritage studies, which are collected as a part of basic data for CFY heritage system as well.

According to the source of data, within the context of the study are of CFY, all the data collected in this research are displayed in five ways: text materials and historical images, open resources online, spatial big data and the fieldwork data by GPS.

3.1.1 Text materials

The text materials of CFY are classified into the primary and secondary sources. The primary sources refer to the original documents coming from the archives and museums both in China and France. The historical facts cited in this thesis are mainly from two books. The official book *Le chemin de fer du Yunnan* (figure 59) was published by CIY in 1910 and now conserved in the Ecole nationale des ponts et chaussées, which is composed by two volumes. The first section recorded the strategic reasons for building the railway and its construction process (Haipong – Vitri – Laocai – Kunming). And the second mainly collected related engineering drawings of the construction process. This book is also translated into Chinese, renamed as "Le Chemin de fer du fleuve rouge et la penetration Française au Yunnan" and was published in 2013.

Then, the book *Compilation of historical materials of Yunnan Vietnam Railway* (figure 60) was published in 2012 by the Yunnan Archive associated with Honghe University, containing all the historical materials in local archives in Yunnan, including railway history, economic history, the modern history of Yunnan, local history and many other sources. The volume I organized the contents of original governmental documents between China and France, which records the process of the losing the railway right and the reaction of local authorities after the construction of railway. And the volume II systemized the related records of CFY in local histories, including the site survey, construction, damages, repairing in the history, the passenger and freight service, as well as the earliest Chinese research on CFY published in 1950s. Therefore, these two books are considered as main sources of the historical records of CFY, providing abundant and authentic materials to support the CFY studies.

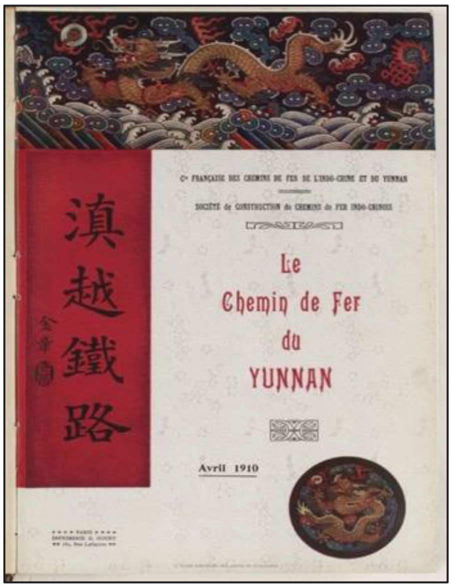

Figure 59, Official publication of Yunnan-Vietnam Railway by CIY

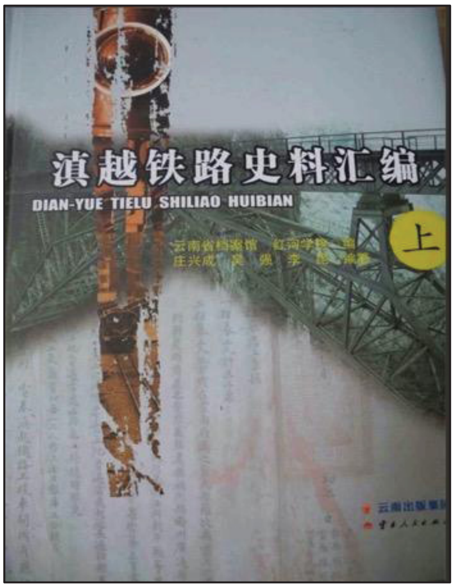

Figure 60, Published book for historical documents in Yunnan

Expect for these two books, the overseas archives conserve lots of original documents, mainly the Archive of Mulhouse and the Archives Nationales d' Orere-mer of Provence in France. The author visited these archives in 2019, systemized and digitalized the related materials for this research. According to the description of catalog in the archive of Mulhouse, the documents of CFY are renamed as the inventories of Compagnie française des chemins de fer de l'Indochine et du Yunnan, which were exported in this archive in 1995. The time span of this series of documents covers from 1873 to 1967[98]. It contains a huge number of materials recording the activities of the CIY company and its photographic records during the process of working, among which the text data relate to details of the structure of the railway company, outline of action, responsible departments, service area, sources of funds, tax, early scientific activities, wartime losses, indemnity from China, treaties signed with China and Vietnam, etc.

[98] From the early expeditions in south east Asia till the end of the French Indochina.

The Archives Nationales d'Orere-mer of Provence is responsible for documenting the French colonial empire, including the colonial Algeria, French Equatorial Africa, and French Indochina. It has imported the majority of the documents and files from the General Government of Indochina, which contains the information of the reports on the works of the study for penetrating China, the technical explorations in Yunnan, the regulation of the recruitment, transport, cantonments, health service, police and other arrangements for the construction sites, as well as the construction volume records and drawings of design for all the sections from Kunming to Laocai to Haiphong. This archive also offers online service for the indexes of all the related colonial documents (figure 61).

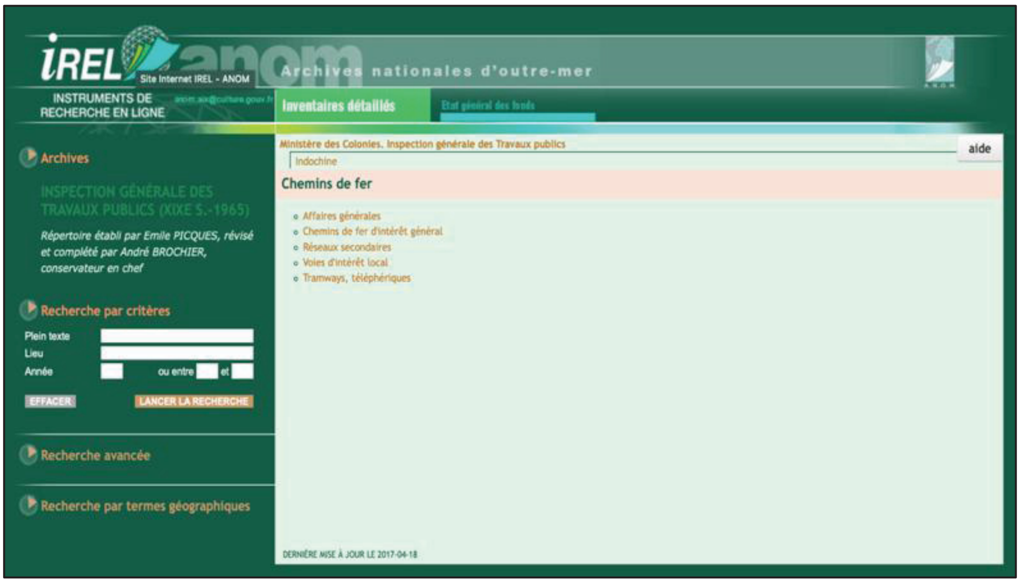

Figure 61, Searching system of the Archives Nationales d'Orere-mer

Among all the CFY archival texts, the ones can be digitalized into database and GIS environment are mainly the population, urban and economic records. For example, the records of *County and City Overview of Yunnan* published in 1944, contains various historical information (population, economy, labor, climate, hospital and historical monuments) (figure 62), which can be translated from paper into CSV formats (Comma-separated values), and then imported into GIS as attribute tables. Then, by the common keywords as references (primary key and secondary key), the tables can be connected with each other and other vector data (figure 63).

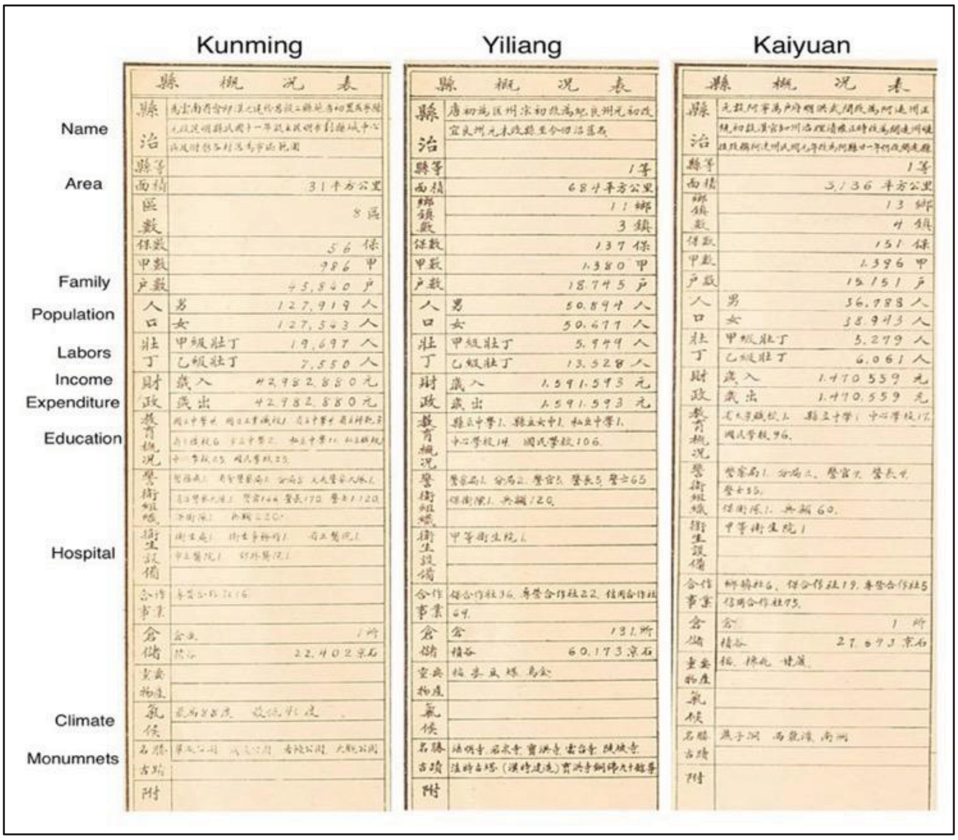

Figure 62, Historical records in the book can be translated into GIS

	field_1	Population1944	male_44	female_44	Labor	Hospital	school	Police	Income	Expenditure	Monuments
1	Chenggong	63130	29772	33358	5516	1	81	124	1628727	1628727	0
2	Chengjiang	70019	35658	34360	2190	1	79	127	3003681	3003681	4
3	Gejiu	50005	27039	22966	3929	1	58	198	832500	832500	5
4	Hekou	31057	15843	15214	4463	0	10	31	115200	227160	0
5	Huaning	83913	40743	43170	7436	1	103	127	1231406	1231406	6
6	Jianshui	156435	77894	78541	6421	1	97	110	410420	410420	0
7	Kaiyuan	36788	38943	75731	11340	1	115	124	1470559	1470559	3
8	Kunming	428282	211141	217141	49180	5	236	1919	44061350	44107444	11
9	Maguan	104191	52347	51844	7334	1	51	90	591500	591500	0
10	Mengzi	102629	47152	55477	6673	1	84	107	1122150	1122150	0
11	Mile	97885	48847	49038	15360	1	90	213	5425809	5425809	0
12	Pingbian	53141	25797	27344	10418	1	7	60	280600	280600	0
13	Yiliang	101571	50894	50677	19477	1	123	196	1591583	1591593	7

Figure 63, The CSV table exported in GIS as an attribute table

The second-hand data indicate the results of former research and publications. For example, the research about the CFY railway stations provides the information on the statue of protection, type of landscape and the administrative division that a historical station belongs to (Chen, 2011; Fan, 2008). The research conducted by the Yunnan Railway Administration: *Cultural relics investigation report on Yunnan-Vietnam Railway and Gebishi Railway* and *The essence of Cultural relics of Yunnan Railway Museum* made the lists of all the related physical remains and movable heritages of CFY, whose locations can be attached on the map to show the distribution and density of railway heritage (YRA, 2013; Zhu, 2017). In the research of HE, the development model of population changes along the CFY is studied. The population data in the cities/counties along the CFY can be obtained from this research (He, et al., 2010) (table 8).

Table 8, Population changes along the CFY

3.1.2 Historical images

Historical images have seldom been studied in previous research on CFY. Utilizing historical maps and photos as a part of heritage system and analyzing the information behind these images is a creative point in this research. Historical images refer to ancient maps, historical remote sensing images, pictures of cultural relic and other historical photographic records. In HGIS studies, ancient maps and historical remote sensing images are the main materials for doing geo-analysis, because they usually contain historical information such as the changes of administrative boundary, land use, place name, as well as natural phenomena such as soil erosion, coastlines and deforestation (Šantrůčková et al, 2015; Pindozzi et al, 2016). They reflect the geographic views, mapping techniques and state of scientific technologies at the time of their creation (Rumsey & Williams, 2002). The historical activities of building railway in Yunnan and Vietnam left thousands of historical images from railway companies/contractors and other individual persons. In this research, the collected historical images include the ancient maps and historical photos of CFY.

Currently, the original CFY images (original negatives) are conserved and protected in various organizations, including Archives Nationales d'Orere-mer in Provence, Archive of Mulhouse, Cite du train in Mulhouse (railway museum), Musée national des Arts asiatiques-Guimet (Musée Guimet), les Entreprises Coloniales Françaises, Institute of Southeast Asian Studies in Singapore (ISEAS) and Ecole nationale des ponts et chaussées. Besides, an online library in USA - University of Texas Libraries owns related series of U.S. Army Map Service (AMS) made in 1954 (figure 64)[99].

[99] The Army Map Service was the military cartographic agency of the Department of Defense from 1941 to 1968. The maps of AMS in this research were made in 1954 for the whole province of Yunnan and Vietnam, called "1954 army maps", cited from:

https://legacy.lib.utexas.edu/maps/ams/china/

The David Rumsey Map Collection[100] also collected lots of general historical maps for Yunnan and Vietnam, relating to historical boundaries and topography in this area (table 9).

Table 9, Organizations and their conserved photographic documents of CFY

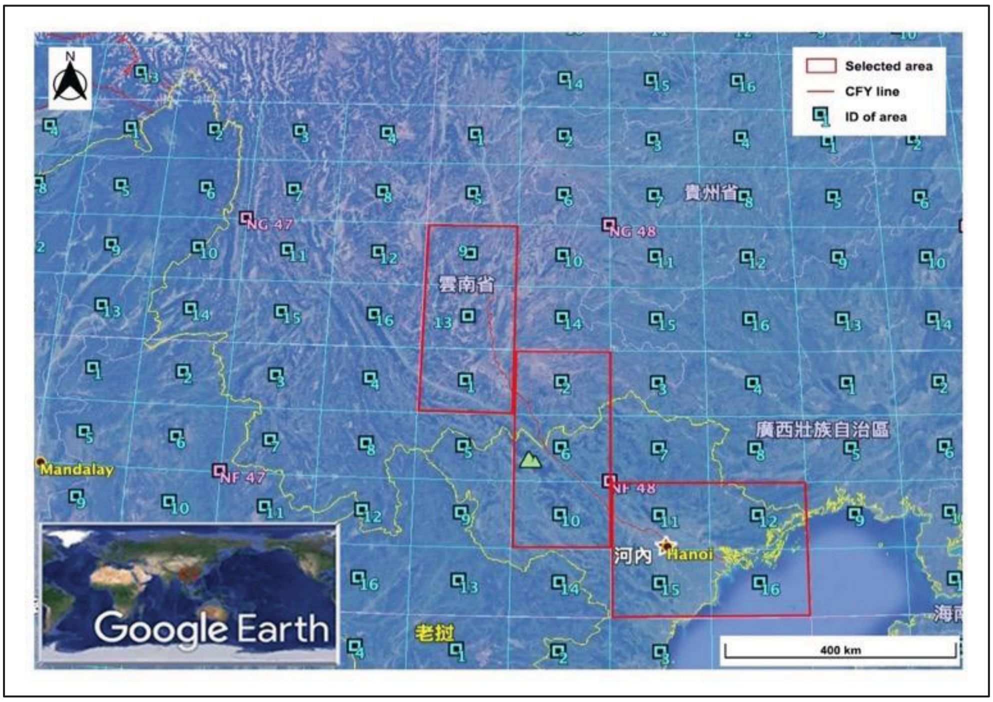

Figure 64, Source of Series of U.S. Army Map Service and the selected map areas (1954)

For these collected photos, the three conformed authors of the photographic works of CFY are considered as important recorders of the visual history of CFY and Yunnan: Auguste Marbotte, Albert Marie and Auguste François[101] (figure 65). Except for

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[100] It is a database of collections focusing on 16th - 21st century maps all over the world, including map atlases, books of exploration, school geographies, pocket maps, manuscript maps and a variety of cartographic materials. Website: https://www.davidrumsey.com

[101] Georges Auguste Marbotte (1861-1936), obtained his bachelor's degree from Lycée Hoche of Versailles. After training, he took accountant as his occupation during the work (1903-1908) for in

these three photographers, there are also numerous anonymous photos conserved in archive or as private collections. The photographic album of CIY stored in Archive of Mulhouse contains thousands of photos recording the construction process for the whole route (figure 66). The bibliothèque numérique patrimoniale des ponts et chaussées owns some anonymous photos published in the book "*Le chemin de fer du Yunnan*"[102]. And the Archives Nationales d'Orere-mer published 24 photos online taken by Têtard René and Busy Léon[103]. Because of their limited amount of works, they will not be considered as the main photographers of CFY in this research.

Table 10, Photographers of CFY

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a subcontractor company named as Waligorski. The official website: www.fleuverouge.fr contains also some published works of Marbotte.

Albert Marie, A French engineer worked for the CIY from 1904 -1907. In 2013, his grandnieces Odile Bernard and Elisabeth Locard published parts of his letters and photos online as descriptions of the daily lives as a foreign technical worker and his observations on locals.

Auguste Français (1857-1935), former French consul in Yunnan, an important photographer in the later Qing Dynasty. The Auguste François Association describes him as an insatiably curious and independent-minded observer. In 1899, he was appointed as the French consul and government delegate in Yunnan. His works connected with the construction of CFY and the explorations in southwestern China. His thousands of photographs combined with writings and films are one of the earliest and most complete documentary photos provided us a historical vision of China.

There are also many other foreign photographers recorded the history of Yunnan and Vietnam such as John Thomson, James Ricalton etc., but they have no relations to the CFY, thus, they are not discussed in this research.

[102] The photos in the published book may be repeated with the originals in the archive.

[103] Website: http://anom.archivesnationales.culture.gouv.fr/ark:/61561/wz818idcda.

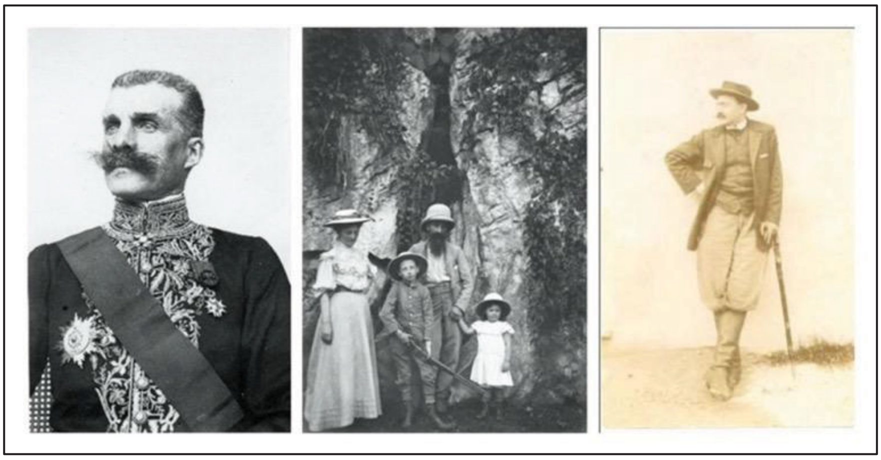

Figure 65, The photo of A. François (left), G.A. Marbotte (center), A. Marie (right)

Figure 66, The photographic album by CIY (section 241km – 356km)

After summarizing all the CFY photos, it is known that there are about 2,000 photographs taken by Marbotte stored in the Musée Guimet. Parts of them are published in the book *Un chemin de fer au Yunnan: L'aventure d'une famille française en Chine* published by his grandson, which is composed by the letters of Marbotte, as well as parts of his drawings and photographic works (Marbotte, 2006). Marbotte's works can be classified into three themes: daily scenes, natural landscape and engineering construction. His photographing equipment, the technique of developing negatives and the method of photo preservation have also been recorded in the book (Marbotte, 2010).

A. François took nearly 1600 photos during his political career in Yunnan and Gunagxi. His photography focused on the details of daily life with a range of topics. Using one of the earliest video cameras created by Lumière brothers[104], he shot a silent movie about Kunming with a duration of 31 minutes, considered as the earliest film documentary in the Asian film history. Most his photos were donated to the Musée Guimet by his wife. In 1985, the museum printed all those photos. In 1999, a film named *Through the Consul's Eye* was published in the USA. In 2000, the book *A Gaze of History: A Record of Kunming's Social Features in the Late Qing Dynasty and Early Republic of China* published parts of his works from 1896-1925 in Kunming (François, 2000). In 1997, a photographic exhibition with about 650 photos was held in Kunming. His remnants are conserved also in other museums, including the Musée du Quai Branly, Musée Angers, Musée Crépy-en-Valois etc.

Different from the others, A. Marie as a railway engineer, did the least amount of photography, but highly correlated with the railway construction. All the 138 remained photos were donated to the Institute of Southeast Asian Studies in Singapore. His major piece of engineering work was a stone arch bridge situated at km 384–385 along the route of CFY, on which he spent a considerable amount of dedication. He also recorded the harsh condition during the construction of Namti Bridge as the most difficult project in the whole construction process (Pholsena, 2015). The values of these historical photographs can be understood from four perspectives:

Firstly, these photographers played as the participants in historical events of CFY. Their photographic works of CFY reflected their personal interests, daily life, and their orientation for French colonial activities. What is in common is their extremely rich topics, covering all aspects of life and the folk customs in Yunnan such as

[104] They are French inventors and pioneer of photographic equipment, also one of the earliest filmmakers.

beggars and vendors on the street, the Chinese traditions and the normal life of railway workers. Their photos open a window for the anthropological studies, showing the Eastern society in the eyes of westerners. Especially, Marie visited a lot the construction site, and his photos expressed his sympathy for the poor local residents and labor under the control of strict company regulations (Bernaed & Locard, 2013).

From the viewpoint of the history interpretation, historical images are valuable documents in an auxiliary position for completing the written history in historical research. The historical images contain the basic information of the author, and time and place for shooting. Compared with the texts, the photos are more vivid, but reading the historical images requires an overall study of the historical context and using of different historical theories to dig deeper meanings behind it such as the narrative function, emotions represented, and the variables inside the context. Therefore, the CFY images as a complement material are one of the important ways to reappear the French colonial history, providing auxiliary evidence for the study of modern railway technology and environmental changes of the regional history in Yunnan (Haskell, 1993).

Besides, the CFY photos own the characteristics of the colonial era in the 19th century. Photography served as a tool for the colonists to explore exotic wonders, landscape architecture, culture and customs. The construction of large-scale projects, such as railways, is a method of economic and military expansion in the colony. Historical pictures were used as mass media tools to shape the image of civilization in the colony. These pictures appeared increasingly in the official documents and other publications of colonial authorities, in order to prove the success of the blueprint projected by Indochina government. Some scholars evaluate the images of railroads, bridges, and railway stations as dramatic and visually attractiveness, showing the victory of French engineers and the power of Western civilization (Srarostina, 2009). They reflected the ambitions of the colonists in Asia and their imagination of spreading "propagation of civilization, freedom, equality and fraternity" (Srarostina, 2010).

From the perspective of heritage protection, these historical photos are also a part of movable railway heritage with great cultural and historical value. They play an indispensable role in the heritage restoration, especially for individual building and infrastructure. The development of modern digital technology gradually overcomes the problems of historical photos - low pixel, distortion or damages caused by improper storage. The digitized historical images of buildings can be analyzed to show rich details of building facades (Condorelli & Rinaudo, 2018). And the photogrammetry based on historical photos is applied in many restoration cases, for example, the restoration of modern buildings in Berlin after the wars (Wiedemann, et al., 2000). And the archival photographs are also sources for the building of 3D models of historical buildings in the historical BIM process (Pocobelli, et al., 2018).

In conclusion, the historical images of the CFY record the personal activities of the French photographers, as one of the historical materials based on the research of the Indochina colony, they were also an important propaganda tool in the colonial era. Nowadays, they are parts of the railway heritage meaningful for the restoration of historical buildings. This study contains the photographic album by CIY, the photos in the published book of A. François and G. A. Marbotte (table 11). For the issues of copyright, not all the historical photos can be used and published, but the digitized photos used in this research got the authorization from Archive of Mulhouse, Cite du train in Mulhouse, and Musée Guimet. The way of importing photos into GIS, extracting metadata and doing spatial analysis based on historical photos is explained in the following subchapters.

Table 11, Historical photos and maps used for this research

3.1.3 Open sources online

Spatial data refer to a geographic location on the earth and its features represented by values in a geographic coordinate system. Spatial data have always been crucial for decision-making activities and many other fields (Van Loenen, 2006). There are abundant spatial data sharing among the GIS communities or scientific organizations. Searching for the online sources of spatial data is another way for collecting data, which is also easier, and timesaving compared with other methods. But they need to be preprocessed to fit for different projects. Based on the different sources on the internet, the main online spatial data used in this research are explained as followed:

Firstly, the basic administrative information of Yunnan and Vietnam is presented as shapefile data on the website of DIVA GIS[105], which offers the general GIS data for all the countries, including the country outlines and administrative subdivisions, inland water, rivers, canals, and lakes, roads and railroads all in vector format. The Natural Earth quick tool[106] provides also the basic geographic divisions on the lands, such as the populated places, urban areas, parks.

The organization GMS provides natural and cultural geographical data for Southeast Asia, which includes the agriculture, forestry, fisheries, biodiversity, demography, environment, land, tourism, transport, and urban information[107]. The collected shapefiles from this website include basin regions, protected areas, airports, soil classification, economic zones and tourism cities.

The climatic data in raster format is collected from the website of World Clim[108]. The social-cultural data of population, distribution of disasters and economic growth is

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105 https://www.diva-gis.org/gdata

106 https://www.naturalearthdata.com

107 https://portal.gms-eoc.org/maps

108 https://www.worldclim.org

also collected as raster from Socioeconomic Data and Applications Center (SEDAC)[109].

Then, the remote sensing data is also used in this research, collected from the free sharing satellite sensors. In this study, the satellite imagery is downloaded from the Sentinel-2, a land observation from the Copernicus Program with large ware width, multi-spectrum and high space-time resolution[110] (table 12). It is applied into the monitoring of vegetation growth, soil coverage, inland river and coastal area environment, as well as the natural disasters such as droughts, floods, volcanic eruptions and landslides. And the Digital Elevation Model (DEM) data from the Earth Explorer[111] can be used for the terrain analysis in geomorphology, surface analysis, satellite navigation, modeling water flow for hydrology, landform 3D visualization and so on. The process of downloading data from Earth Explorer is explained in figure 67.

Table 12, Parameters of the Sentinel 2-A sensor

There are also other raster data in this research collected from online sources: forest cover, biodiversity and cropland data from the global forest watch[112], land cover/ land use change data from Climate Change Initiative (CCI) viewer and NASA[113]. Table 13 systemizes all the vector and raster data from the sources online.

Table 13, Sources of online GIS data

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[109] https://sedac.ciesin.columbia.edu/data/set/

[110] Sentinel-2 is Consisted of 2 identical satellites: Sentinel-2A and Sentinel-2B. Sentinel-2A satellite was launched in 2015, and Sentinel-2B in 2017. In this research, the data from Sentinel-2A is selected. Website: https://cds.climate.copernicus.eu.

[111] https://earthexplorer.usgs.gov

[112] https://www.globalforestwatch.org/map/country/CHN/3

[113] CCI: http://maps.elie.ucl.ac.be/CCI/viewer/download.php. NASA: https://earthdata.nasa.gov

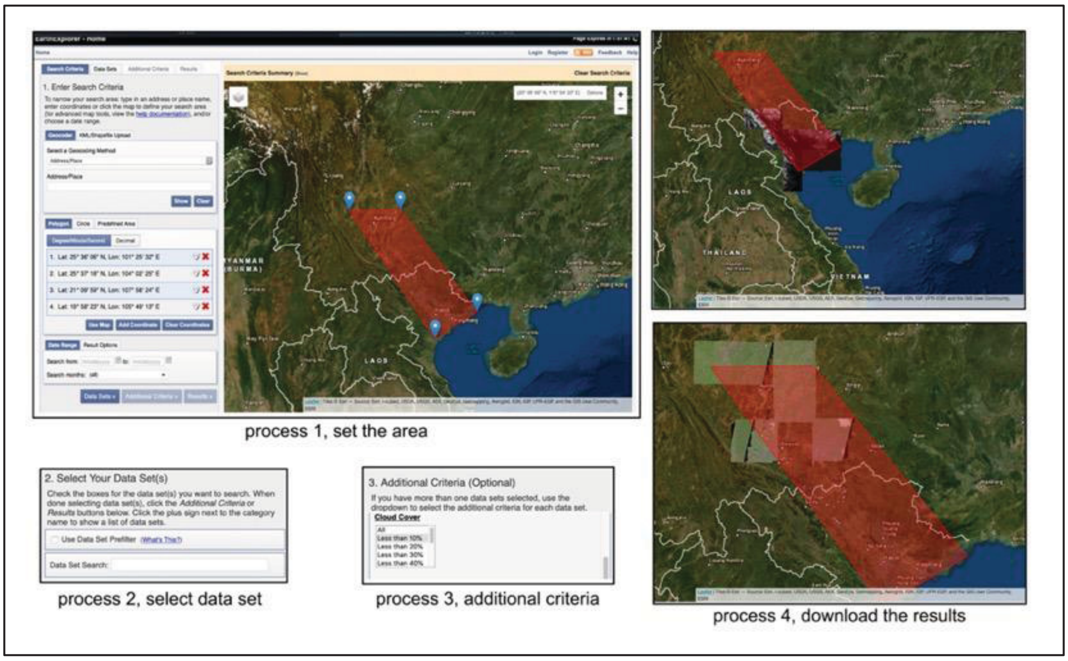

Figure 67, Process of downloading data from Earth Explorer

3.1.4 Spatial big data

Spatial big data is the spatial-temporal data collected through devices embedded GPS receiver or the user behavior data from social media such as the geotagged photos on blogs (Facebook, Twitter, Weibo, Flickr, Instagram, etc.). The emerging of big data brought breakthroughs for the traditional research on space and place, which leads to new perspectives for interactive research between human and geography. The movements of a large number of people in geographic space generated the digital footprints, which can be used to predict user's activity pattern and their social relations (Wenger, 2008; Carson, 2008), the interactive characteristics between spatial units, the sentimental perception of visitors, and the land evaluation in a dynamic environment (Lee & Chung, 2011; Zheng, et al., 2012). The empirical research driven by big data can obtain a larger sample size with lower cost and shorter cycle. But big data can also be random, verbose and subjective. Thus, the data quality needs to be controlled through a large amount of preprocessing, data mining and machine learning technologies (Thatcher, 2014).

Within the field of cultural heritage, the use of big data has radically changed the way of heritage protection, tourism and exhibition. As more and more data generated through the Internet in forms of text, video and pictures sharing on the social network, these data can be collected on basis of data mining, to be expressed in charts, maps, and schematic diagrams. After translation into useful information, the multimedia information can be used to analyze the feelings, opinions, and satisfaction of the visitors/users by the text analysis and image recognition, to serve again for visitors to meet their cultural needs and personal preferences, through the three-dimensional dynamic interactive map and virtual reality to improve the heritage experience (Bolchini et al. 2007).

Among all the types of spatial big data, Point of Interest (POI) is a main source based on the function of geographical locations. POI has lots of forms such as the everyday locations of public services (shops, markets, parks, libraries, stations, tourist attractions, hotels, restaurants, etc.), and the geographically significant points (historical monuments, heritage sites, scenic spots, etc.). POI is strongly connected with online maps, and the map services on mobile phones make the identification and monitor of POI simpler and easier.

In this research, the spatial big data of CFY is mainly composed by two types of sources, namely, the geotagged photos from social network (Sina Weibo and Flicker[114]); and POI from online map service (Baidu map and Open street map[115]), including the location of touristic attractions, accommodations and other public services for heritage tourism in the study area. To collect the POI data from online maps, the application "Ebay collector"[116] is applied, and for collecting the geotagged photos from social media apps (Sina Weibo and Flicker), the application "Houyi collector" is utilized[117]. The algorithm of data mining by these two applications will not be discussed in this research.

Further spatial analysis can be done with the help of GIS to support the heritage management and tourism based on these big data. For example, using the information of the location of geotagged photo from Weibo and Flicker, the heatmap can be made to quantify the degree of popularity of touristic sites within the study area. And using

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[114] Sina Weibo is a popular Chinese micro-blog similar with Instagram. There are not many Chinese users on Instagram, so it is not selected as a source for big data for this research. Website: weibo.com. Flicker is an image hosting service and video hosting service. Website: https://www.flickr.com

[115] Baidu map is a web mapping service application created by Baidu, it offers satellite imagery, street maps, street view, as well as other traveling functions such as a route planner. Website: https://map.baidu.com.

Open Street Map (OSM) is a free editable map of the whole world. Website: https://www.openstreetmap.org

[116] A software developed by EBay Software Engineering (Shanghai) Company Limited for collecting spatial data on online maps. Official website: http://www.ebay.com

[117] Houyi Collector is a webpage collector software developed based on Google search and artificial intelligence technology, which is powerful and easy to operate. Official website: http://www.houyicaiji.com

the POI data of CFY (bridges, tunnels and railway stations), the density of railway heritage in study area can be qualified to reflect the technical value of the railway. Table 14 shows the sources of the spatial big data for this research and their formats in GIS.

Table 14, Sources of spatial big data

3.1.5 Fieldwork data

Fieldwork is a way for collecting raw data in the fields, which is widely used in various disciplines, through the observation of nature, interview or observe people, or collect spatial data by digital tools (smartphone, GPS, drone, etc.).

The fieldwork in this research aims to record the heritage and landscape along the route of CFY in the main tourist attractions in both Vietnam and Yunnan. The device used in this research is the smartphone (iPhone) to locate the coordinates of these sites based on the GPS system. When a receiver receives a signal from satellites, the position can be computed and stored as coordinates. Various machines have different precision for the collected GPS data, for example the accuracy of a continuous GNSS station can be less than 0.5 cm. Then, the accuracy may be influenced by weather, size of study area, accessibility of terrain and physical obstructions. But the using of smartphone with GPS sensor also becomes increasingly popular for location determination. And the accuracy of location-based service by smartphone was examined in some studies, showing that the horizontal position error ranges from 0.05 m to 99.7 m, and an average error of iPhone device is about 9.9 m (Oshin, et al., 2012; Merry & Bettinger, 2019).

The author made three times of fieldwork during the three-year-research along the route of CFY, to experience the trip by train from Kunming to Laocai till Haiphong. Except for the sections shut down (Kaiyuan - Hekou), other parts were experienced on the train (Wangjiaying – Kaiyuan; Laocai – Hanoi – Haiphong). For the sections without transportation access, the author also walked along the rail in some parts to collect data (Kunming - Wangjiaying) (figure 68-69).

Figure 68, Recording the trip along the rail by foot (Yangzonghai)

Figure, 69 Recording the trip on the train

The photos from fieldwork are imported into GIS as point dataset for that the photos captured by GPS devices or smartphones contains the coordinates information, which can be matched with the geographic coordinates on the WebGIS or other GIS applications. In QGIS, it provides a plugin "Import Photos" for importing photos into GIS environment (figure 70). This tool can be used to create point feature classes from geotagged photo files, where the original data saved in the photo are imported as attribute information, such as the file name, storage path, device type, date and time of photo shoot, altitude, longitude and latitude. Then, these created point features can be modified, managed, and analyzed with the geoprocessing tools in GIS. These modern survey photos can be used as tourism supported information to let the visitors preview the scenes of the CFY sites before visiting. And the modern photo can also be compared with historical photos to analyze the historical landscape changes.

However, for the accuracy of the GPS in smartphone device, and the limited time of fieldwork, not all the sites along CFY can be recorded. Especially, some parts of the CFY sections are not easily accessible or identifiable. For example, the Laocai - Hanoi section provides only night trains, the observation is hard to be proceeded in this section. Thus, this research just shows a general location of the photos taken during the fieldwork and their metadata attached. The form of the metadata of photos is shown in table 15 as an example. There are also a large number of online photos of CFY sites and heritages shared through social media (Weibo and Flickr), whose locations can be extracted for further analysis. However, for the copyright of the photos, they cannot be imported directly as the site records in the CFY database.

Table 15, An example of the description of metadata of fieldwork photos

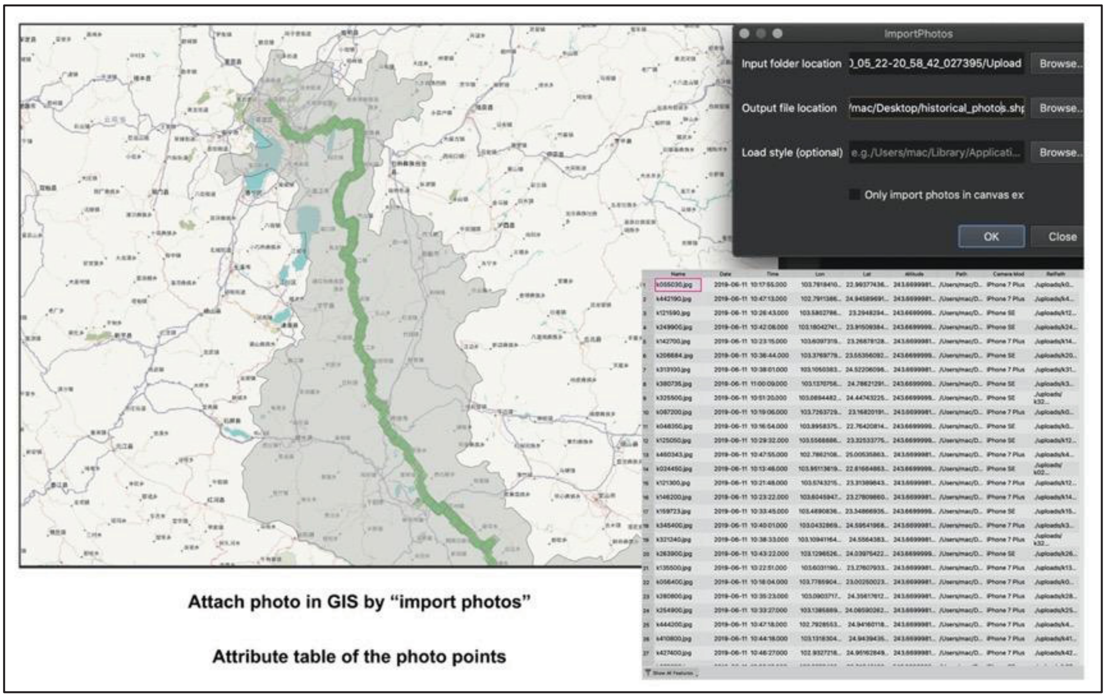

Figure 70, Attaching photo in QGIS by "import photos"

3.2 Data classification

According to the theory of GIS science, spatial data in GIS can be split into three main categories: vector, raster and tabular data, among which vector and raster are spatially referenced, and a table of data is linked to a feature class or raster if they have a common attribute. In the environment of GIS, vector means expressing the geographical features as geometrical shapes (points, polylines, and polygons). Points are pairs of coordinates, representing for simple locations like wells, peaks and cities. Polylines are sets of coordinates defining linear features such as railway, streets, trails and rivers, and the polygons define enclose areas like lakes, forests, boundary of countries etc. Each of these geometries always link with an attribute table with the row representing a feature and the column for a piece of information to describe the feature. In general, vector data is smaller in storage, easier to be updated, maintained and re-projected, compatible with relational database, and simpler with geoprocessing.

Raster data is a type of digital image represented by grids. Pixel/cell is the smallest single unit building an image. A raster has a specific number of pixels, and each pixel contains a single value representing information as an identifiable representation of the abstraction of reality. The raster data can be classified into thematic data, spectral data (satellite imagery), and imagery (scanned picture). Comparing with vector, the data structure of raster is simpler, more powerful for advanced spatial analysis. It also has advantages in representing continuous surfaces and performing faster overlays with complex datasets (Esri, 2016).

As a result, for the collected data for CFY heritage system, it can be first organized by their form (vector, raster and table categories). The polygon dataset includes features such as the distribution of vegetation, water area, urban area, eco-regions and protected areas etc.; the polylines dataset contains the CFY rail line itself, other railway system, rivers, highway, and other roads; the points dataset includes city, scenic sites, industrial sites, the scattered heritage elements as stations, bridges, tunnels, and the sites where historical and fieldwork photos were taken.

Then, the thematic raster data includes the DEM, forest coverage, biodiversity, LULC urban area, population and climatic data; the imageries contain the georeferenced historical maps and geotagged historical photos. And the satellite images refer to the Sentinel-2 products. There are also other tables involved, such as the statistics of economic and population growth and the list of railway heritage (figure 71).

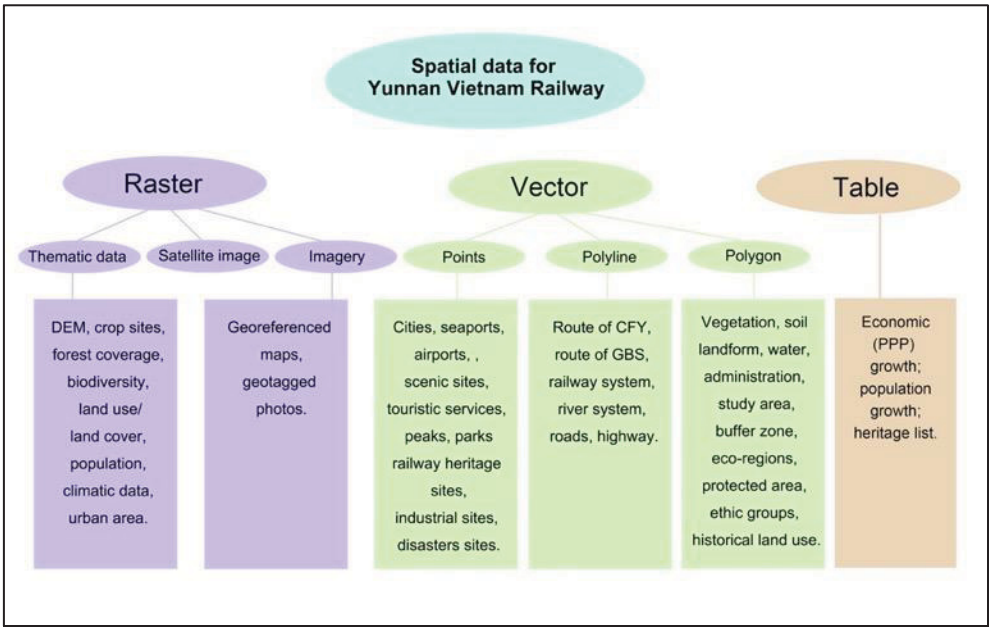

Figure 71, Classification of data in the database based on data type

According to the topic of data, they can be also classified into two categories: natural geographic data and cultural geographic data. Then, in the category of cultural geographic data, they are further classified into heritage related and other aspects (figure 72). This way of classification of data is also used in the organization of data models in the relational database in this research. Currently, all the vector data are stored in the format of Shapefile, the raster in GeoTiff format, historical images in JPEG format. After the classification, the data are still needed to be preprocessed, georeferenced and managed in the database, to be prepared for the constructing of CFY heritage corridor.

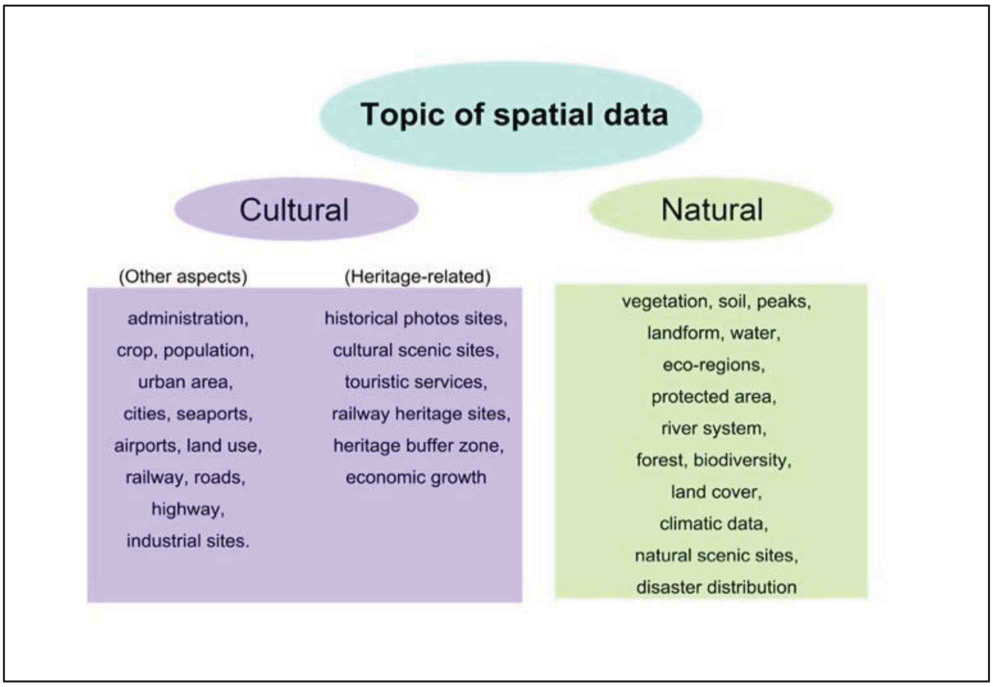

Figure 72, Classification of data on the topic

3.3 Data preprocessing

Geospatial data has some characteristics and specialties. For example, their formats are strongly associated with the using application; the storing size may change along with the development of computer technology; they may require extensive contents for further interpretation and periodically reprocessing for different purposes and uses.

After data classification, no matter the required data from open sources or these translated from historical documents or the big spatial data from internet, all these geospatial data cannot be used directedly. Because they own different data formats, coordinate systems, map projections, data resolution, data units, etc. There could also exist some redundant data or errors, which will influence the accuracy of analysis result. Thus, preprocessing is in need as an operation to adjust various spatial datasets, to remove the errors and redundant data for further analysis and view of accurate data.

The preprocessing may include redefining the boundary of data, reducing errors and noise, georeferencing, conversion of data format, coordinate system and map projections, raster-vector conversion, spatial interpolation, spatial data fusion, resampling, enhancing and mosaic of raster, and many other operations. As follows, the data preprocessing is discussed according to four data formats within the defined study area, namely the preprocessing of vector data, thematic raster data, remote sensing imagery and other non-spatial images.

3.3.1 Preprocessing of vector data

Firstly, coordinate system and map projection need to be unified for all the datasets. The collected vectors have different coordinate systems, for example, the World Geodetic System 1984 geographic coordinate system [118] and WGS 84/ Pseudo-Mercator[119] and other regional projections. In order to facilitate further analysis and calculations, in this research, all the maps are made and displayed under the projected coordinate system - Universal Transverse Mercator (UTM)[120] based on the WGS 1984 datum. This projection minimizes distortion within every UTM zone, suitable for large and medium scale mapping. Among all the zones, the UTM 48N zone covers the extent between 102°E and 108°E, which is properly matched with the study area from 102° 43' 12" E to 106° 42' 54" E. Thus, the data with other coordinate systems need to be converted by the tool of reprojection to the projected coordinate system "WGS84/ UTM zone 48N" (figure 73).

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118 A reference coordinate system used by the Global Positioning System, based on the WGS 84 datum. It is recognized internationally by the Global Position System.

119 A variant of the Mercator projection for Web mapping applications, such as google maps and Open street map.

120 Developed in the early 1940s by USA, it is based on the transverse Mercator projection, delivering high accuracy in its zones.

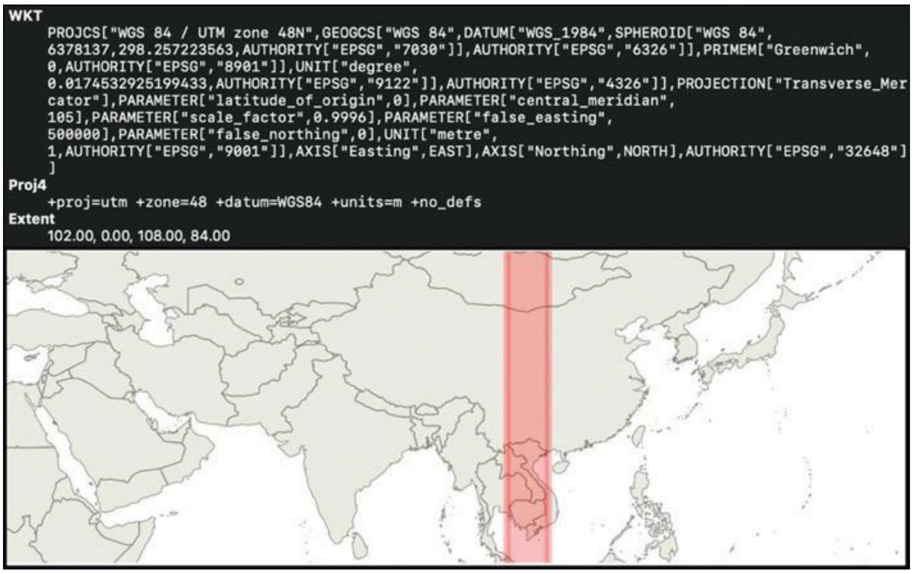

Figure 73, Parameters of UTM zone 48N

However, the Online Chinese maps utilize the Chinese standard datum according to the *Surveying and Mapping Law of the People's Republic of China*[121]. The most popular geographic coordinate systems in China are GCJ-02 (Colloquially Mars Coordinates) for Gaode Map and BD-09 (Baidu Maps Coordinate system) for Baidu Map, which are both based on the GCJ-02 datum. The big data in this research are collected from online Baidu map, which needs the transformation from BD-09/GCJ-02 to WGS 84 datum. There are many tools available online for this conversion, the "LU tool" is used for the conversion[122], and its algorithm will not be discussed in this research. Figures 74-75 show an example of conversion of big data from BD-09 to WGS 84, and an offset can be reached up to 890 meters between these two systems. Then, they are re-projected to the UTM zone 48N from WGS 84 as well.

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[121] There are many ellipsoid shaped datums with different basepoints to represent the Earth's surface. The coordinates with different datums can have offsets of a couple of meters or several kilometers. The law is formulated in 2002, aimed for strengthening the administration of mapping in China. For the Chinese national defense and security, it is different with other international datums. It can cause some offsets for the use between Chinese standard datum and other datums.

1	Name	BD coordinate		WGS coordinate		City	Source	Type
2	万家凹生态Park	103.14484	24.908499	103.1363606	24.90558543	Kunming[Yiliang]	Baidu Map	Park
3	涌金Park	103.044585	24.964338	103.0362217	24.961491	Kunming[Yiliang]	Baidu Map	Park
4	宜良Park	103.166478	24.919493	103.1580259	24.91660501	Kunming[Yiliang]	Baidu Map	Park
5	盘江森林Park	103.178713	24.904736	103.1702788	24.90186669	Kunming[Yiliang]	Baidu Map	Park
6	乡鸭湖购物Park	103.174625	24.918477	103.1661849	24.91560045	Kunming[Yiliang]	Baidu Map	Park
7	三角梅主题花海	103.151569	24.957628	103.1430981	24.95471643	Kunming[Yiliang]	Baidu Map	Park
8	邑和Park	103.217007	25.202801	103.2086305	25.19995075	Kunming[Yiliang]	Baidu Map	Park
9	马蹄湾景区-售票	103.263249	25.069001	103.2548764	25.06615521	Kunming[Yiliang]	Baidu Map	Scenic resort
10	叠虹桥景区售票	103.390013	25.073952	103.3813944	25.07082416	Kunming[Yiliang]	Baidu Map	Scenic resort
11	宜良九乡Scenic	103.390505	25.088458	103.3818862	25.08532808	Kunming[Yiliang]	Baidu Map	Scenic resort
12	月亮谷	103.315789	25.111724	103.3073295	25.10877619	Kunming[Yiliang]	Baidu Map	Scenic resort
13	柴石滩水库Scen	103.349292	24.996808	103.3407478	24.99378064	Kunming[Yiliang]	Baidu Map	Scenic resort
14	宜良九乡Scenic	103.389162	25.070976	103.3805444	25.06784988	Kunming[Yiliang]	Baidu Map	Scenic resort
15	Yiliang岩泉寺Sc	103.134746	24.930137	103.1262586	24.9272117	Kunming[Yiliang]	Baidu Map	Scenic resort
16	叠虹桥景区	103.400033	25.055855	103.3914045	25.05271391	Kunming[Yiliang]	Baidu Map	Scenic resort
17	张湾村二区36号	116.706237	39.860399	116.6936781	39.85342831	Kunming[Yiliang]	Baidu Map	Scenic resort
18	阳宗海Scenic res	103.257318	25.058111	103.2489489	25.05527124	Kunming[Yiliang]	Baidu Map	Scenic resort
19	太阳谷Scenic res	103.179668	24.695487	103.1712326	24.69263366	Kunming[Yiliang]	Baidu Map	Scenic resort
20	观音阁	103.15368	24.919899	103.1452107	24.91699424	Kunming[Yiliang]	Baidu Map	Scenic resort
21	太和楼	103.176738	24.918156	103.1683011	24.91528245	Kunming[Yiliang]	Baidu Map	Scenic resort
22	地下倒石林	103.390505	25.088458	103.3818862	25.08532808	Kunming[Yiliang]	Baidu Map	Scenic resort
23	宜良普济桥	103.268351	25.009696	103.2599725	25.00685079	Kunming[Yiliang]	Baidu Map	Scenic resort
24	仙子洞景区	103.132467	24.571627	103.1239765	24.56871256	Kunming[Yiliang]	Baidu Map	Scenic resort
25	西浦	103.176561	24.918232	103.1681238	24.91535819	Kunming[Yiliang]	Baidu Map	Scenic resort
26	岩泉禅寺	103.139088	24.931668	103.1306038	24.92874621	Kunming[Yiliang]	Baidu Map	Scenic resort
27	怀古园	103.192033	24.977262	103.1836204	24.97440253	Kunming[Yiliang]	Baidu Map	Scenic resort
28	有居蘑菇屋	103.047415	24.963788	103.0390423	24.96093391	Kunming[Yiliang]	Baidu Map	Scenic resort
29	养身园	103.157402	24.923353	103.1489375	24.92045251	Kunming[Yiliang]	Baidu Map	Scenic resort
30	Yiliang匡远九乡	103.162303	24.92331	103.1538451	24.92041593	Kunming[Yiliang]	Baidu Map	Scenic resort
31	船心船意	103.14523	24.928031	103.1367514	24.92511567	Kunming[Yiliang]	Baidu Map	Scenic resort
32	青龙寺	103.256245	24.82393	103.2478709	24.82111584	Kunming[Yiliang]	Baidu Map	Scenic resort
33	宜良商会林	103.155455	24.924468	103.146988	24.92156492	Kunming[Yiliang]	Baidu Map	Scenic resort
34	财神殿	103.153757	24.920242	103.1452878	24.9173373	Kunming[Yiliang]	Baidu Map	Scenic resort

Figure 74, Conversion from BD09 to WGS 84 (Online tool)

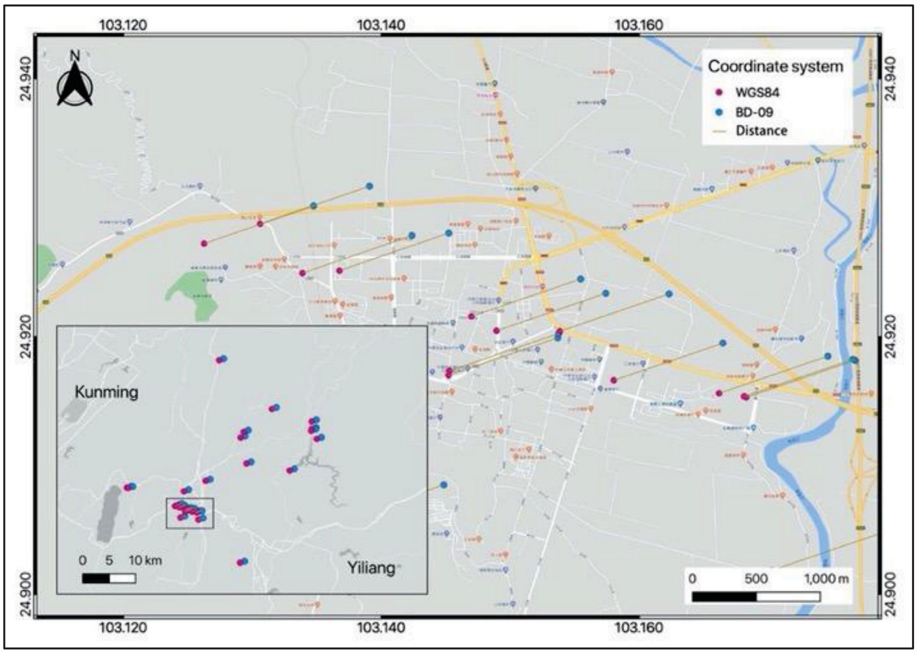

Figure 75, Offset between BD-09 and WGS 84

[122] https://tool.lu/coordinate/

Secondly, the collected data usually have the extents not exactly matched with the defined study area. Thus, the collected vector data needs to be clipped within the study area to remove redundant information or merge some data with small scales together. All the vector data will be clipped into the study area before doing analysis. The figure 76 is an example of explaining the preprocessing of parts of the collected data (railway, river and water body), which are clipped and united from the national scale into the scale for the study area.

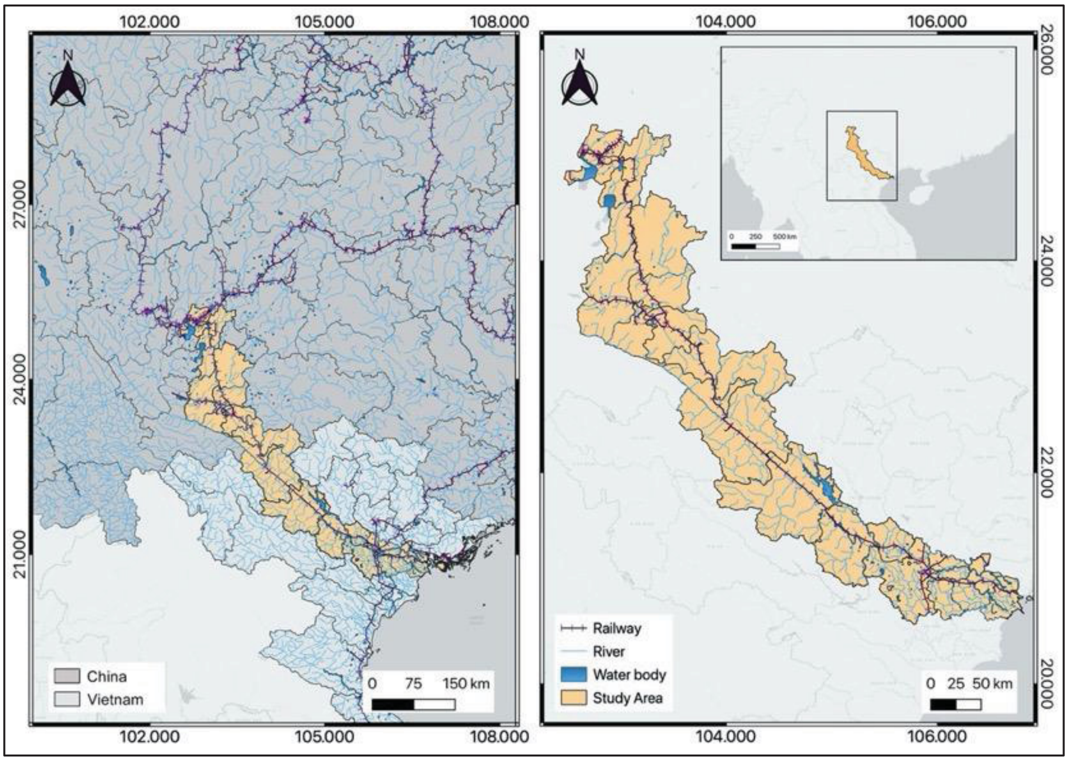

Figure 76, Clip and union vector data in study area

Afterwards, conversions between raster and vector formats allow a project to make better use of both two formats, and to solve spatial problems more flexibly. The method of converting points to raster through the continuous known points to estimate values for other areas is called "interpolation". The most popular methods of interpolation are the Inverse Distance Weighted (IDW) and Triangulated Irregular

Network (TIN). In this research, the collected population and economy data are interpolated from point data format into rasters.

IDW is utilized to interpolate the vector data of economy and population in the study area. "IDW determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locational dependent variable. This method assumes that the variable being mapped decreases in influence with distance from its sampled location (ESRI, 2016)."

As is shown in figure 77, the excel data of global population and economic growth (from 1990-2005) is collected from the Center for International Earth Science Information Network, which are attached with the spatial location of control points for each country/ city. Through the information of latitude and longitude of every control point, it can be imported to GIS system from the CSV form. Each control point has the value of both population and economic growth rate. Based on these values, other areas without control point can be estimated as a continuous raster surface by the IDW interpolation tool in QGIS (figure 78). The interpolated raster indicates the growth trend of population and economy in the study area for further analysis and evaluation.

Besides, there are also other preprocessing operations of vector data in this research to make sure the accuracy of study, such as checking the geometry errors of vectors, removing the repeated and redundant data, which will not be explained in detail in text.

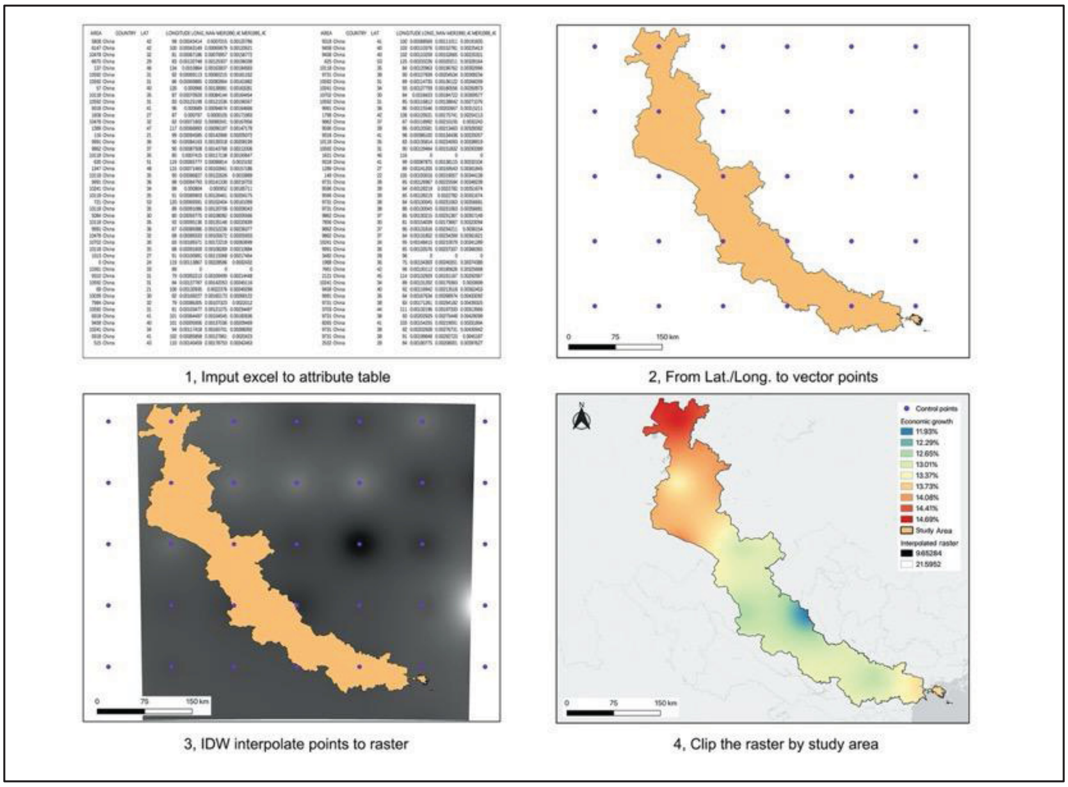

Figure 77, Process of interpolation

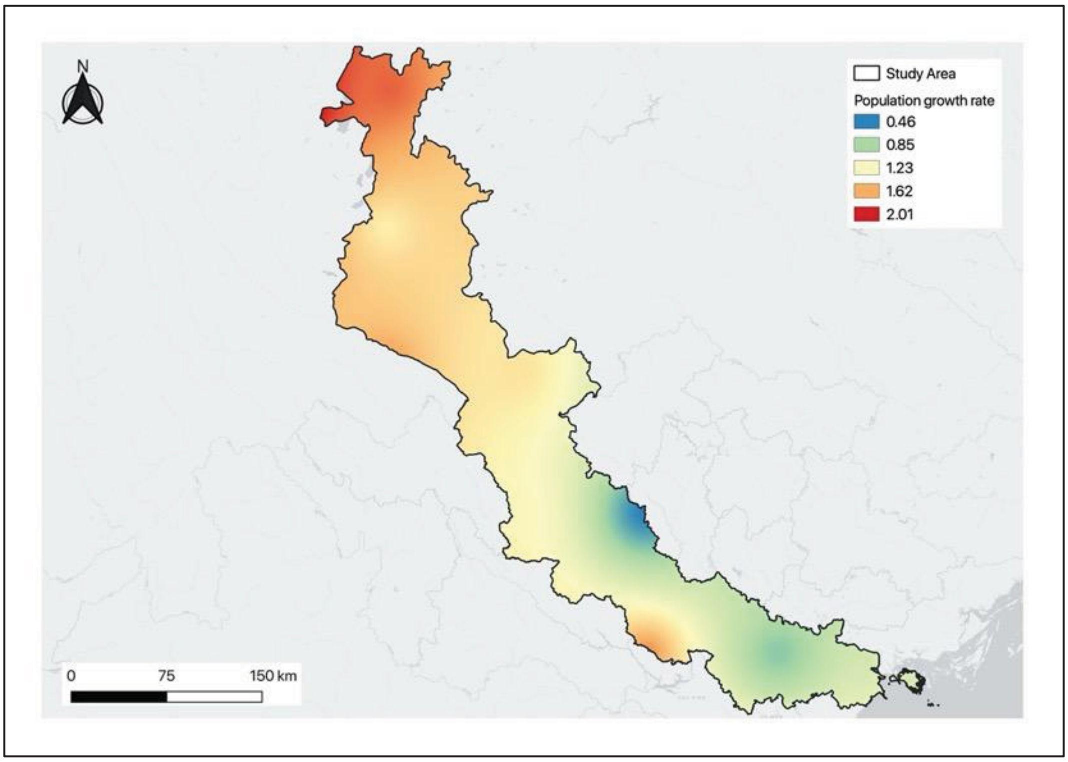

Figure 78, Result of the interpolation of population data

3.3.2 Preprocessing of thematic raster

In this study, the collected thematic raster data contains the DEM, LULC, population, biodiversity value, forest and crop coverage, precipitation and temperature data. Same as the vector data, the raster needs to be, firstly, re-projected into the projected coordinate system WGS84/ UTM zone 48N and clipped/ merged into the defined study area. The process is same as processing the vector data, but with different processing tools for raster, such as clip raster by mask and the wrap tool for reprojection. The results are shown in figure 79-81 for each raster in the research.

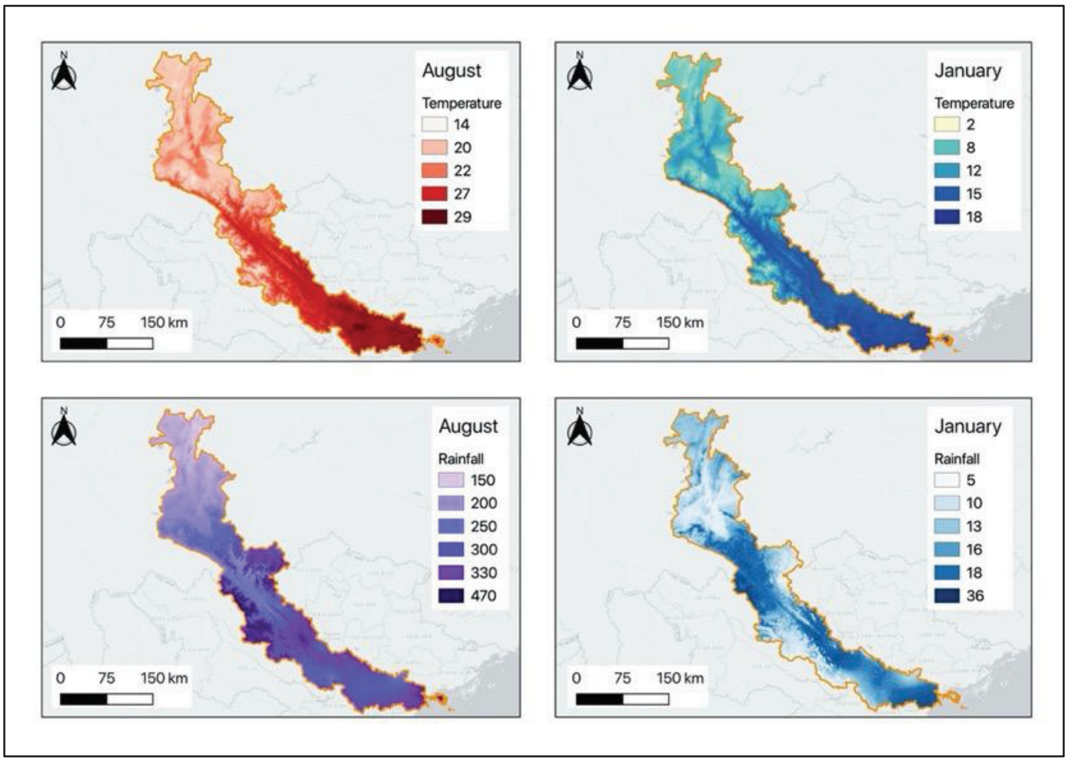

Figure 79, Clipping climatic raster in study area

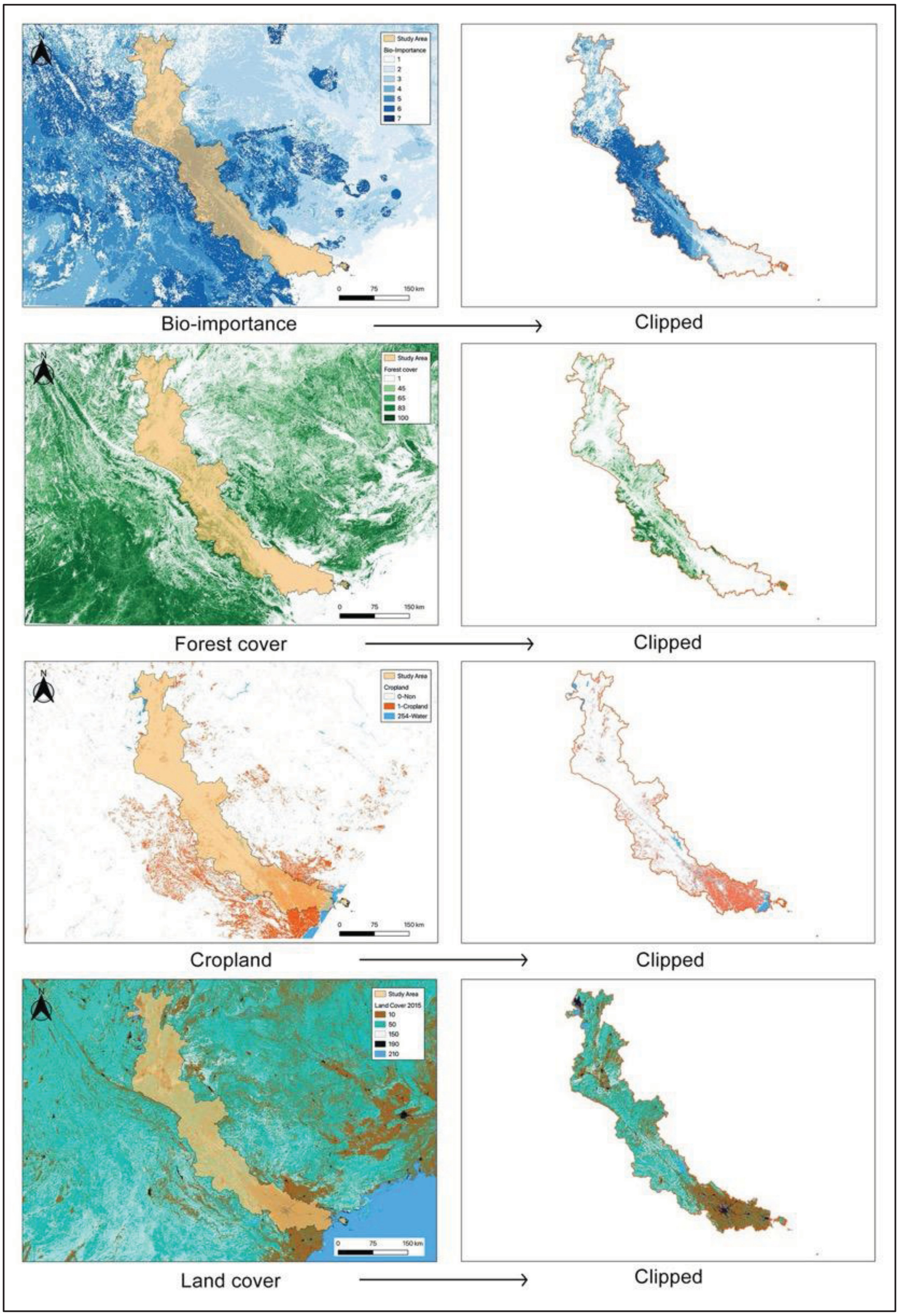

Figure 80, Result of clipped raster in study area

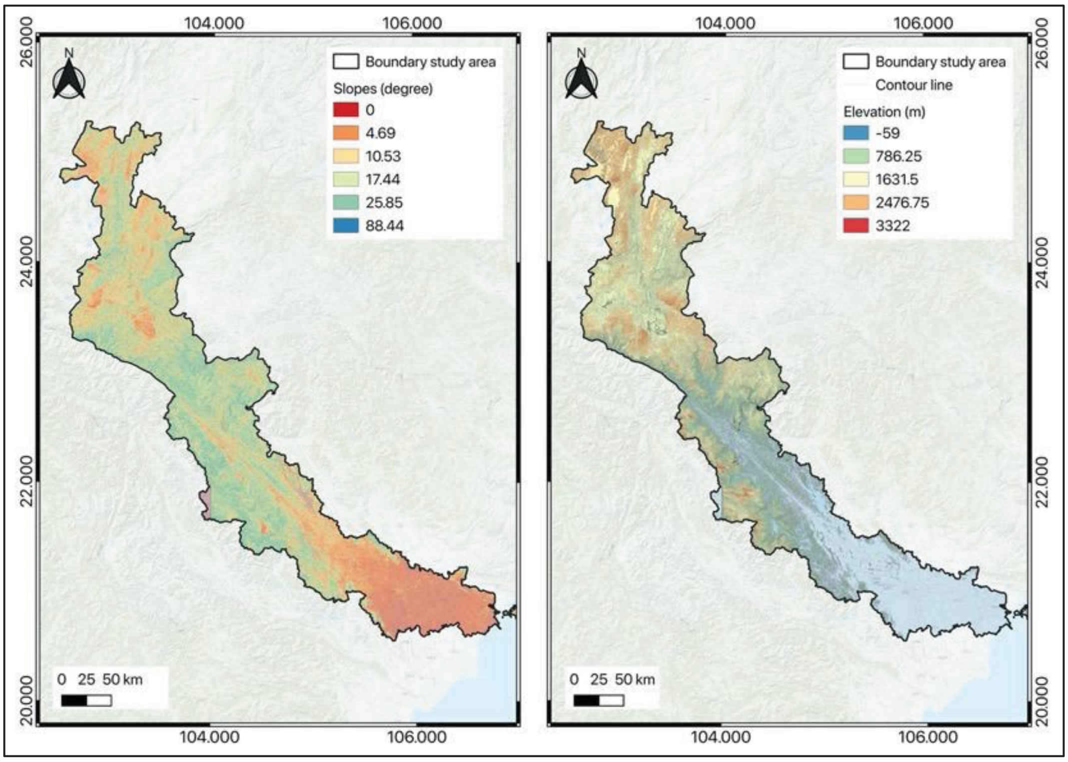

Figure 81, Result of clipped DEM in study area

After the reprojection and clipping, raster data are still stored with different pixel/cell resolution, for their original cell sizes are diversified from a regional/national scale or a worldwide scale as following: pixel of land elevation is 29 m; land use 460 m; population density and population count 1075 m; biodiversity value 26 m; forest 26 m; crop coverage 167 m; rainfall and temperature 1075 m. In general, smaller cell size of raster means a higher resolution and spatial accuracy, which requires more storage space, and a larger cell size intends lower resolution and spatial accuracy, but with less storage space.

When dealing with multiple raster datasets and combining rasters of different resolutions, same pixel resolution needs to be settled to make sure the accuracy and consistency for further analysis. The selection of suitable spatial resolution of raster is related to the scale of the study area. For the map with scale of 150,000 m, a resolution of nearly 75 meters would be sufficient for further analysis (ESRI, 2010). Thus, in this research, the pixel resolution is settled to be 50 m to make sure the accuracy. The processing of resampling is required to draw repeated cells from the original data samples. A Resampling tool in QGIS provided by Geographic Resources Analysis Support System (GrassGIS) is used to alter the spatial resolution of raster and set rules for aggregating values across the new cell sizes (figure 82). In the resampling process, the nearest neighbor assignment method is used.

"Nearest neighbor assignment is the resampling technique of choice for discrete (categorical) data since it does not alter the value of the input cells. Once the location of the cell's center on the output raster dataset is located on the input raster, nearest neighbor assignment will determine the location of the closest cell center on the input raster and assign the value of that cell to the cell on the output raster." (ESRI, 2019)

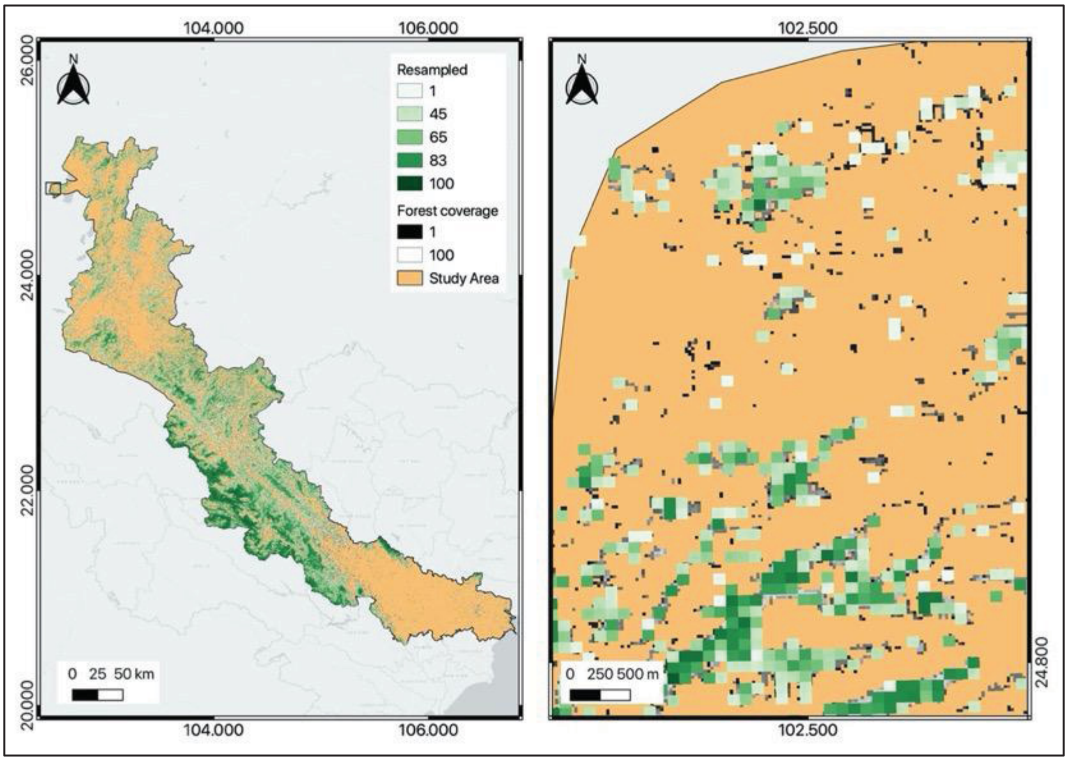

Figure 82, Resampling of raster from 25m to 50m

3.3.3 Preprocessing of remote sensing imagery

Preprocessing of remote sensing image refers to the image restoration and rectification, which are caused by the radiometric and geometric distortions. The geometric irregularities come from the land relief, the perspective of the sensor optics; the motion of the scanning system; the location of platform, etc. Radiometric correction intends to reduce the radiometric errors and inconsistencies caused by the environmental factors such as the atmosphere, terrain, and land surface, especially, the scattering and absorption of aerosols and molecules in the atmosphere result in the shadow in pixels. A specific process of preprocessing is depended in different sensors and remote sensing products.

As is explained, satellite imagery in this research is mainly obtained from the Sentinel-2 sensor launched by European Space Agency (ESA) and the Moderate Resolution Imaging Spectroradiometer (MODIS) imageries from the United States Geological Survey[123]. The MCD12Q1 Version 6 data product provides supervised classification data of global land cover data, which does not need the atmospheric corrections. Then, Sentinel-2 images own high spatial and temporal resolution, which is specifically designed for the use of vegetation/agriculture monitoring and many other fields. A standard-2 level-1C product of Sentinel-2 is geometrically refined in UTM/WGS84 projection, and each band is stored in a separate JPEG file. The noises from geometric errors have already been removed, thus, the reprojection is not necessary for this product, but the atmospheric corrections are still needed for this kind of data product.

[123] From website: https://lpdaac.usgs.gov/products/mcd12q1v006/

Various atmospheric correction methods have been developed and studied in different cases. Semi-Automatic Classification Plugin (SCP)[124] is used to do the atmospheric correction and further processing of Sentinel-2 imagery in this research (Congedo, 2016). The Dark Object Subtraction (DOS) in SCP is an effective atmospheric correction method, which relies on the quality and availability of the dark target. It is an image-based technique to correct the additive haze component for satellite imagery (Chavez, 1988). Although, its accuracy is generally lower, it can still improve the estimation of land surface reflectance. After the atmospheric correction, clipping and merging process, the remote sensing imagery within the study area is shown in figure 83-84 with RGB (red-green-blue) true color composite (Bands: 4-3-2).

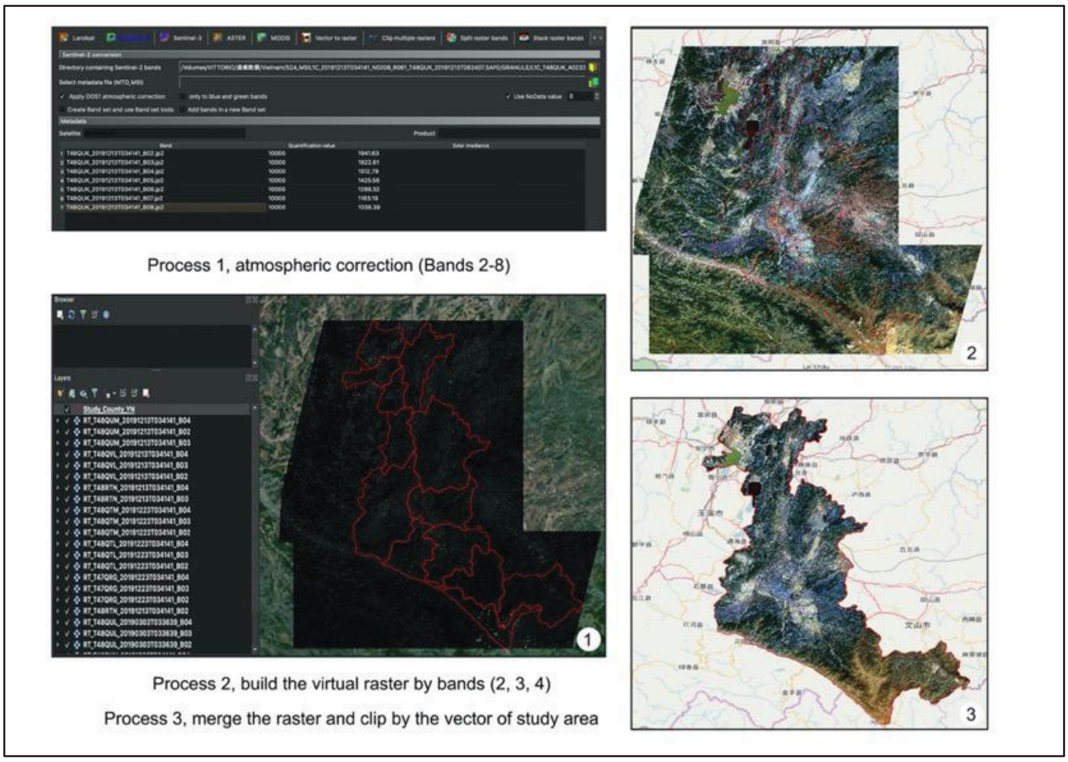

Figure 83, Correction of remote sensing image

[124] SCP is a free open source plugin in QGIS developed by Luca Congedo, which supports the supervised classification of remote sensing images, as well as other functions such as downloading, preprocessing, postprocessing, and raster calculation.

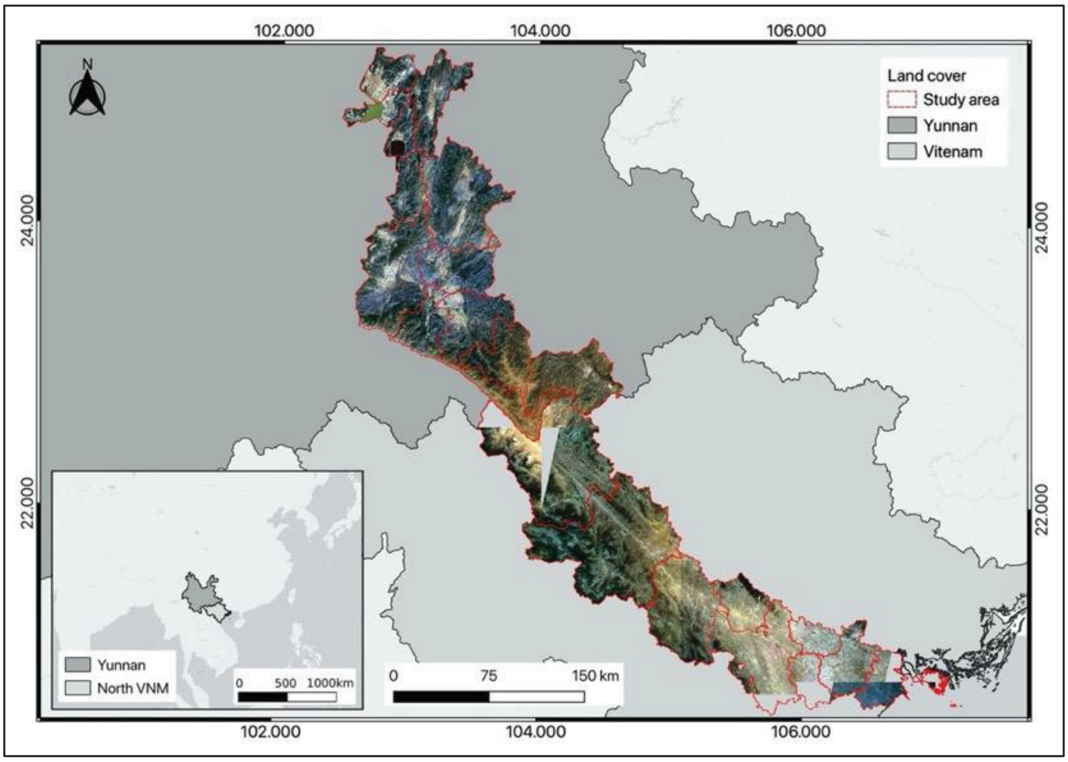

Figure 84, Result of clipping and merging of remote sensing image

After the preprocessing, in this research, the MODIS is used for the comparison of historical land use changes, and the Sentinel-2 images are mainly used to obtain the vegetation information through the Normalized difference vegetation index (NDVI). The NDVI is a graphical indicator for assessing whether the land surface being observed by live green vegetation. The NDVI value ranges from -1 to 1, a high value means a high possibility of dense green vegetation. It is calculated the difference between NIR (vegetation strongly reflects) [125] and red light (vegetation absorbs) as the following formula: NDVI = $\frac{(NIR-Red)}{(NIR+Red)}$

Th value of NDVI is widely used for assessing the distribution of vegetation, productivity and dynamics of crops, monitoring of deforestation, and the ecological

[125] Near-infrared, part of range of the electromagnetic radiation spectrum.

effects of disasters (Pettorelli, et al., 2005). An example of calculating NDVI in QGIS by the field calculator is shown in figure 85 within the study area in Yunnan. The NDVI in Vietnam is also calculated and then merged with the area in Yunnan.

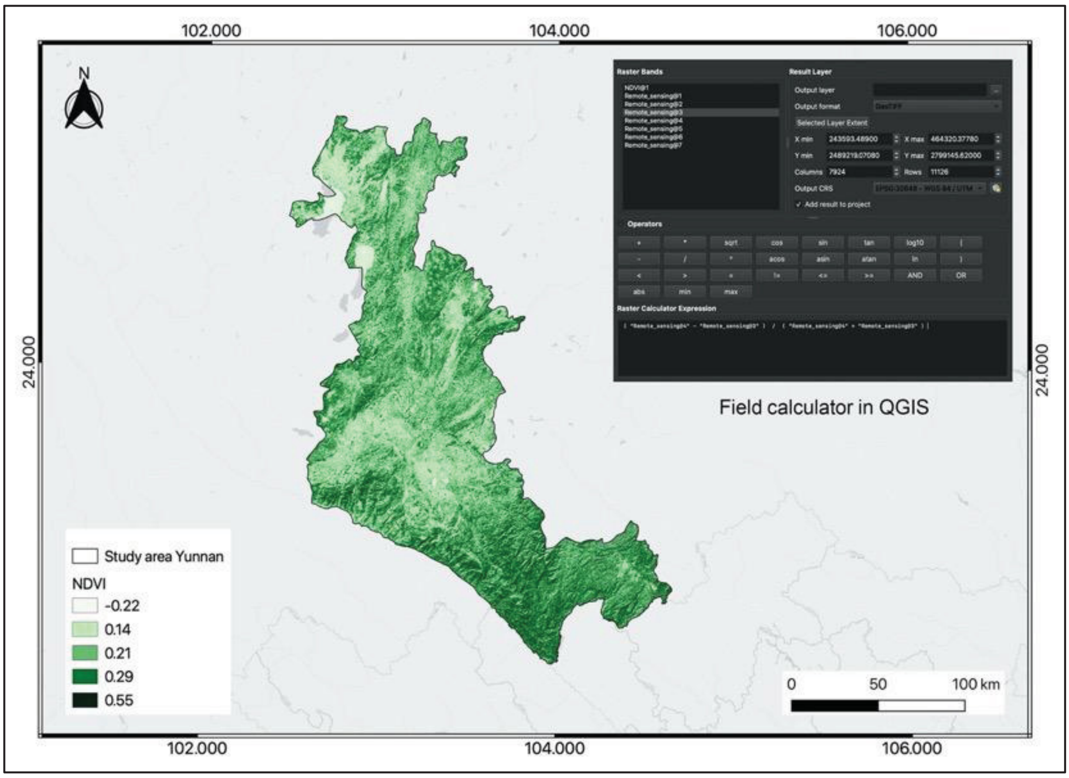

Figure 85, Result of calculating NDVI

3.3.4 Georeferencing and digitalization

Georeferencing is a process of transforming an arbitrary coordinate system of a raw image into a map projection or geographic coordinate system, to make it aligned into a real-world map or a known coordinate system. Scanned images and maps usually do not contain spatial coordinate systems or cannot fit rightly with a coordinate system. In these cases, the coordinates need to be added or corrected. Thus, a georeferenced raster can be displayed, queried, and analyzed in GIS environment and extracted more useful information. Meanwhile, the photos without coordinates can be added to a geographic location as the process of geotagging, which can be analyzed in GIS, too. In this research, the georeference process refers to the georeferencing of historical maps and geotagging of historical photos.

For geotagging the historical photos of CFY, there are mainly three ways: 1) the photos with specific title and descriptions can be easily interpreted and understood, the coordinates can be gained from the Google Earth and then added to the photo (figure 86); 2) The photos named by the engineering measures indicate its distance from the railway terminal (Hekou station is settled as the original point), their locations can be estimated by the recorded distances; 3) The photos without titles are hard to be identified, thus, the method of comparing the surroundings and find the landmarks can be used, and their locations are estimated roughly in this research[126]. After geotagging, the location of photos can be imported into GIS and online maps for further analysis and management. The research of user-generated geotagged photos has a great contribution to the tourism industry, which enhanced the travel experience and travel decision-making (Wilson, et al., 2012). Based on the geotagged historical photo and the photo taken by the current tourists, a comparison can be made to reveal the historical landscape changes.

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[126] In order to find the precise location of the shooting places, more studies need to be done by the historians. For the limited information of these photos, they can be only geotagged roughly.

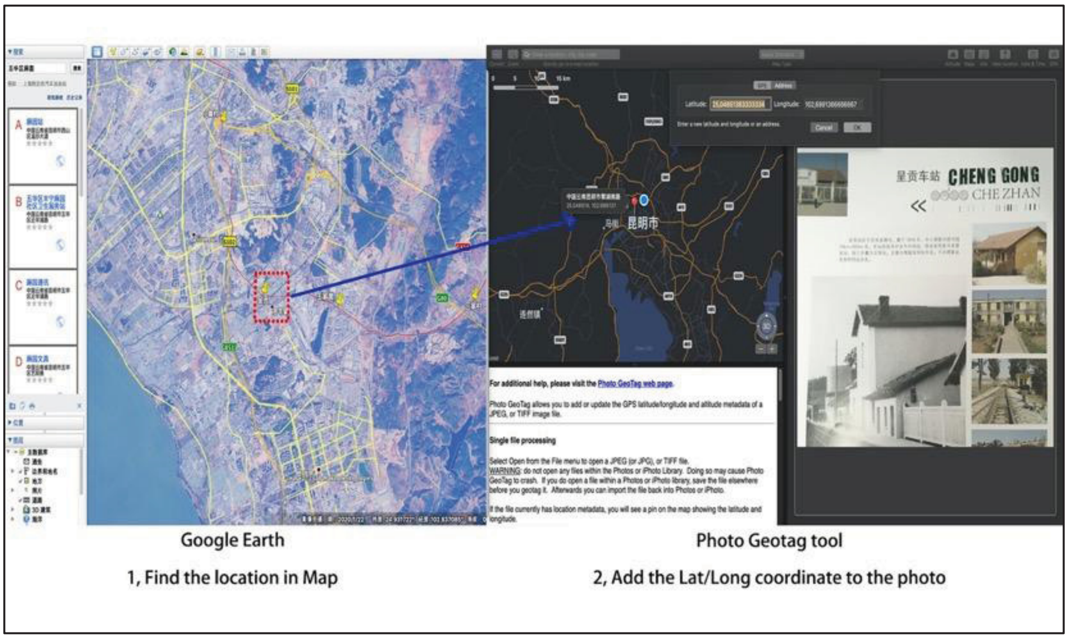


Figure 86, Process of geotagging historical photos

However, the localization of historical photos is not that accurate, and many of the historical photo sites are not accessible anymore since some sections of CFY have already been closed, or to find the same perspective with the historical photo is also hard. The identification of the location of all the historical photos and the process of repeat photography still need a long time to finish with the cooperation with more historians and other scholars. In this research, these photos are considered as a supplementary material for understanding the historical landscape. The rough locations of these photos are shown in GIS and published on WebGIS with their metadata shown on map. Then, a general description of the topic of every photo can be identified, and classified into forest, cropland and uncultivated land. In this way, the historical photos can be also compared roughly with the historical land use data, to indicate the historical changes (figure 87).

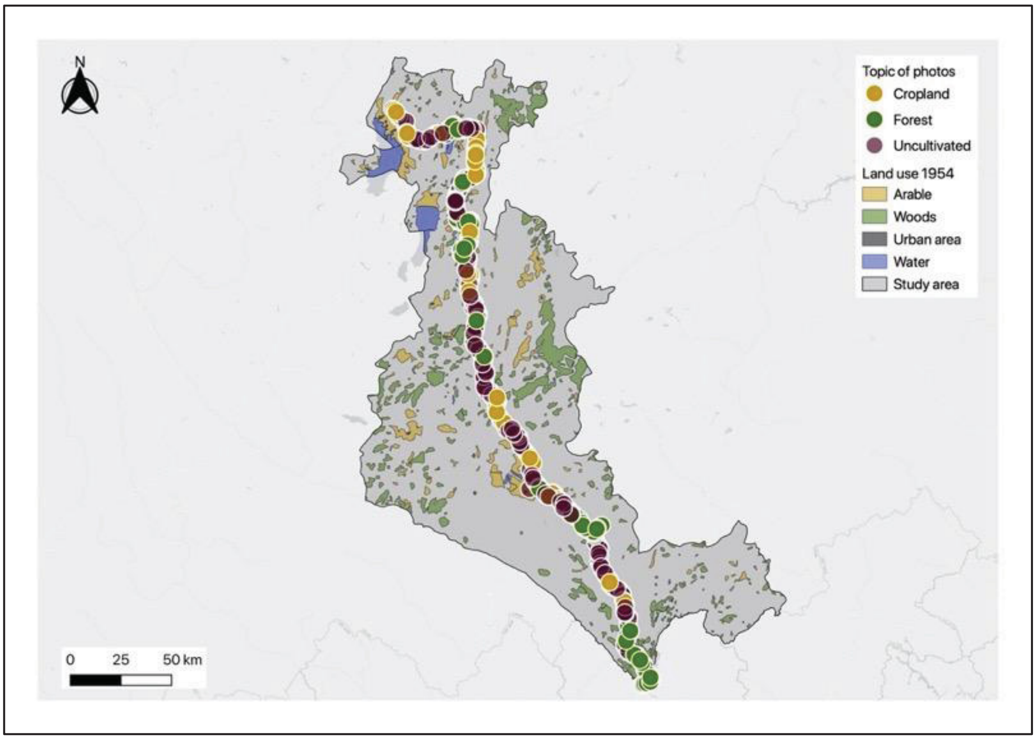


Figure 87, Identify the photo topic and compare with historical land use

For georeferencing historical maps, the transformation method utilizes new referenced pixel-center to trace back to the original image, copying the values of the closest pixels to the new pixel. The main steps in a georeferencing process include: choose a suitable GIS reference dataset as base map; identify the projection and coordinate/ datum system of historical map; select control points to connect the historic map with reference dataset (Piovan, 2019). The stable features in the map such as intersections of roads, stations, bridges, buildings, or monuments are usually used as the control points to align with the known objects in the reference map. To determine the values of pixels in output image, a resampling process is required, such as the nearest neighbor method, bilinear interpolation, cubic convolution and so on. For the fast process and closest value-resampling, nearest neighbor is tested as conservative and suitable for georeferencing historic cartography and applied in this research.

The 1954 military maps made by USA Army are well made with the UTM projection, clear title, codes, scale and legends (figure 88). Thus, the Open Street map in UTM zone 48 is selected as a base map for the georeferencing. Figure 89 shows the process of georeferencing in this research. At first, there are in all ten 1954 historical in needs of georeferencing. For each map, seven points of the location of railway stations or city locations are used as the control points for their easier identification on the map. The linear transformation method and nearest neighbor resampling method are applied for the transformation. Then, all the georeferenced maps are united as three sections (Kunming-Bisezhai-Hahua-Haiphong) shown in the GIS. As a result, the three parts of historical maps are attached in GIS environment, and the final average residual pixels are 26 meters (figure 90). The extent of study area is nearly 50,000 km^2, and the maps in this area are usually displayed with a scale of 1: 150 km. Thus, the average error is within an allowable range.

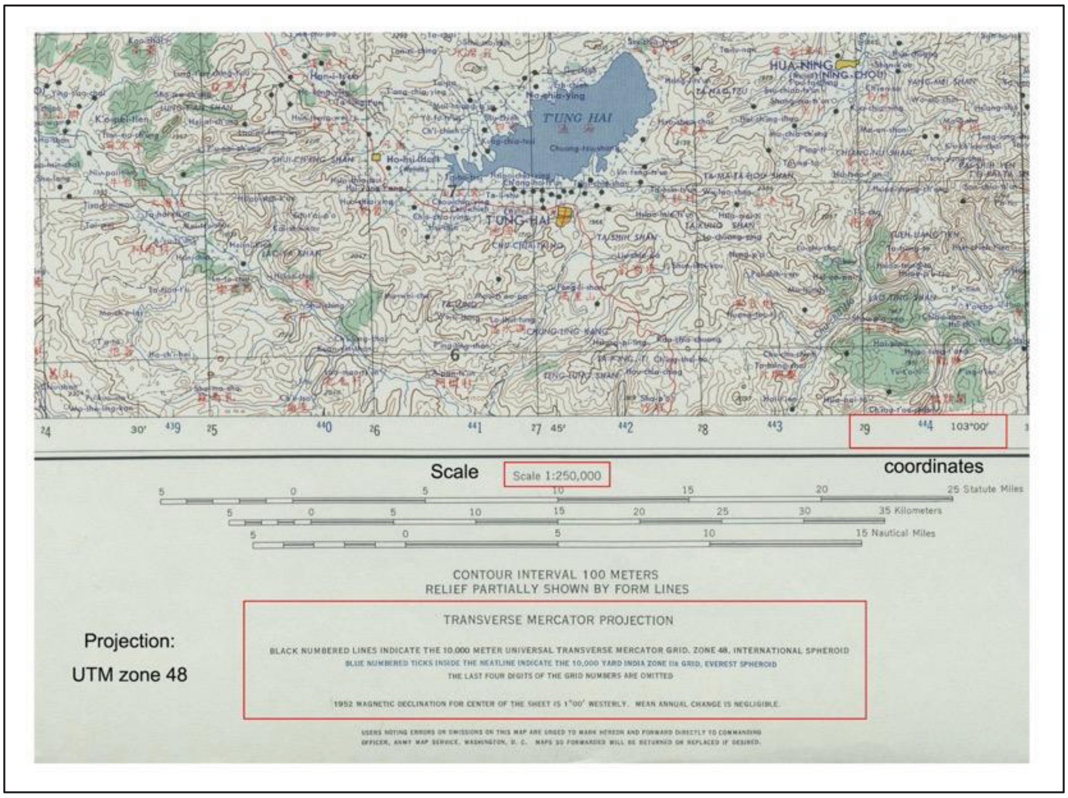


Figure 88, projection in the historical map (Military map 1954)

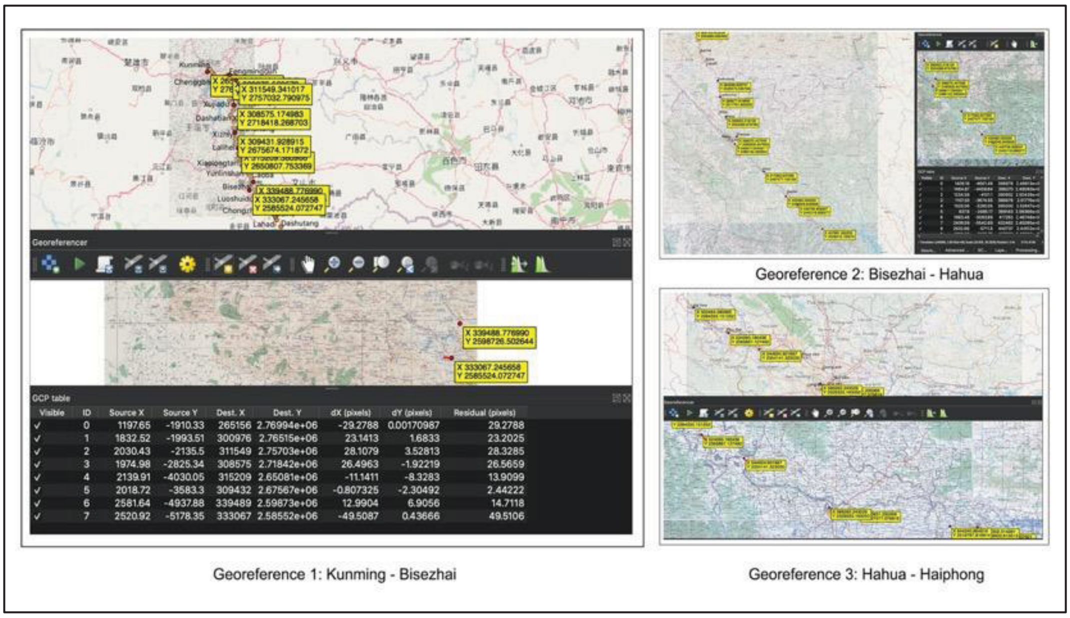


Figure 89, Process of georeferencing in QGIS

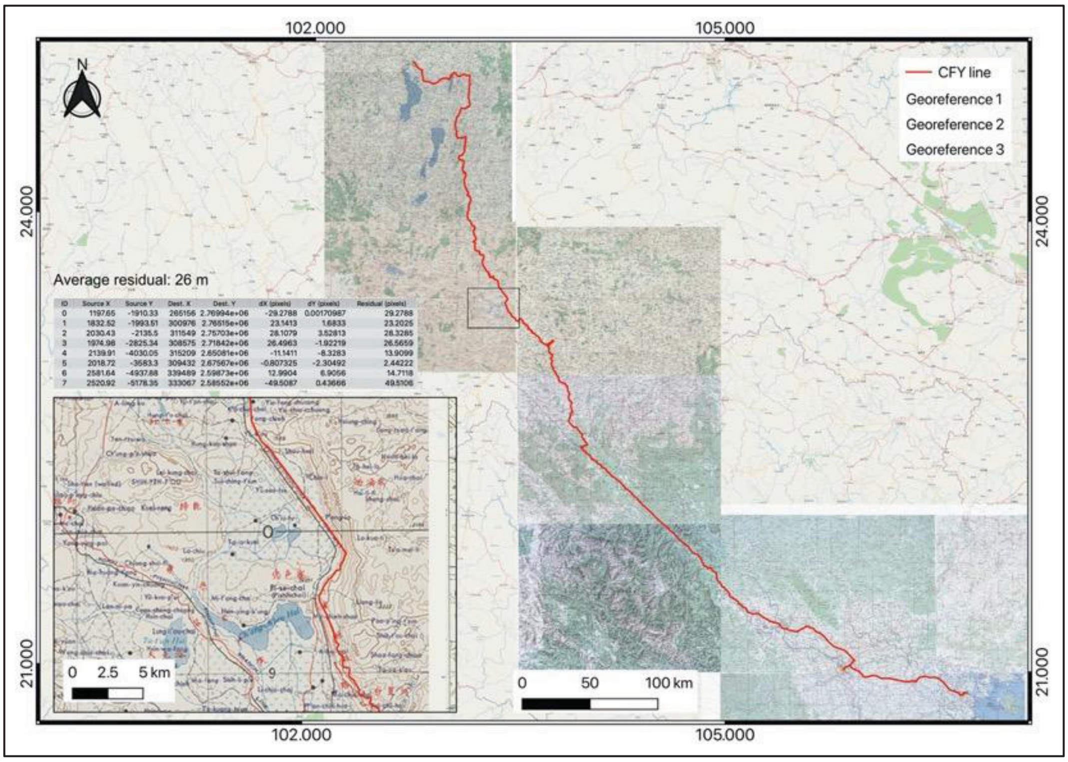


Figure 90, Result of georeferenced 1954 military maps

Then, eight historical maps made in 1898 for recording the site survey from Hanoi to Haiphong are also georeferenced. However, these hand-made maps have rough accuracy and unidentifiable projection, which cannot fit well with the current dataset (figure 91). Therefore, the geographic features of 1898 survey maps will not be extracted and analyzed further in this research. Other maps such as the maps made in 1944 from Yunnan Department of Civil Affairs describe mainly the historical place names of specific cities in Yunnan, which is not the topic of this study. Also, the large-scale maps contain less spatial information (country boundary, railway route, river system) for this study (figure 92), which will not be further georeferenced, but they can be seen as a part of movable railway heritages of CFY.

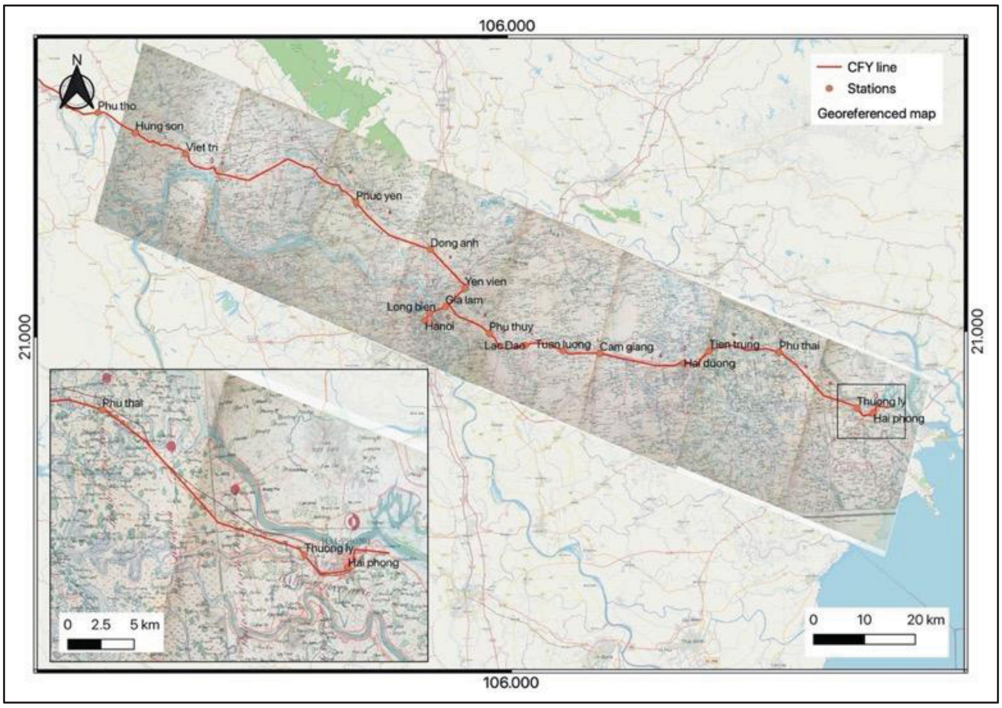


Figure 91, Georeferenced 1898 maps

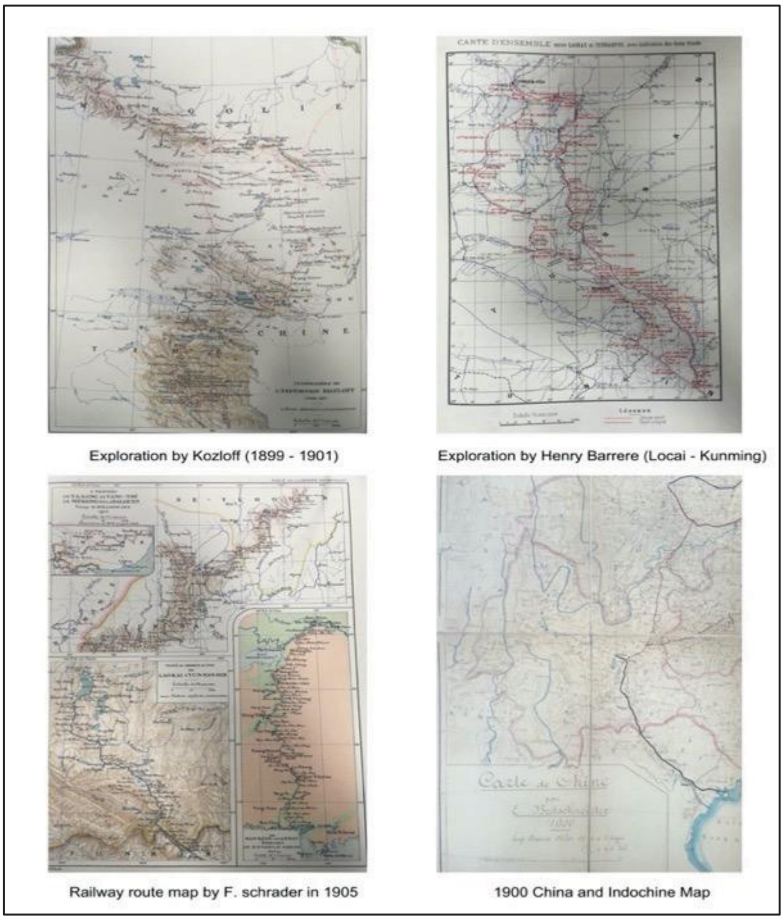


Figure 92, Other historical maps in archive

After georeferencing, a georeferenced historical map in GIS can be a source to extract useful spatial information as new vectors, for example, the historical buildings and monuments can be digitized as points, and historical land cover areas can be translated as polygons. Once the geographic features from historical maps are digitized, they can be analyzed and compared with other historical maps or current GIS data. In this research, the georeferenced 1954 military maps are used to interpret the historical information.

These series of maps were made by the USA army in 1954 with all same scales of 1:250,000. The legend of map is readable and clear in both English and French, containing the classes of cities, roads and the location of transportation terminals. And the land cover classified the water body, rapids, salt evaporator, swamp, mangrove, rocks, foreshore flat, woodland, constructed area and rice paddy, among which woodland and rice paddy are more identifiable (figure 93). Thus, the digitalization process in this study mainly intends to the vectorization of the land covers of woodland and rice fields. Obtained the digitalized vector layer of land cover in 1954, further analysis can be done to show the changes of land use between 1950s and nowadays (with MODIS data), especially for the increase or decrease of forest and agricultural areas (figure 94). The land use change analysis is done in the next chapter after the construction of heritage corridor.

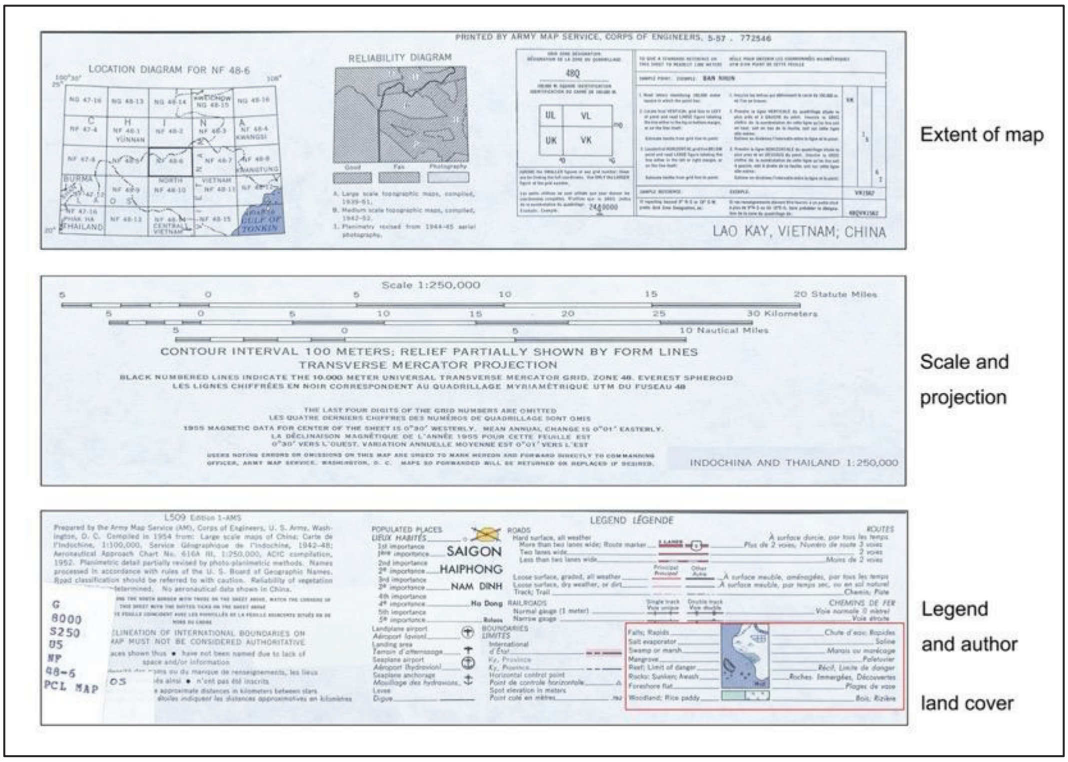


Figure 93, Text information in the 1954 military maps

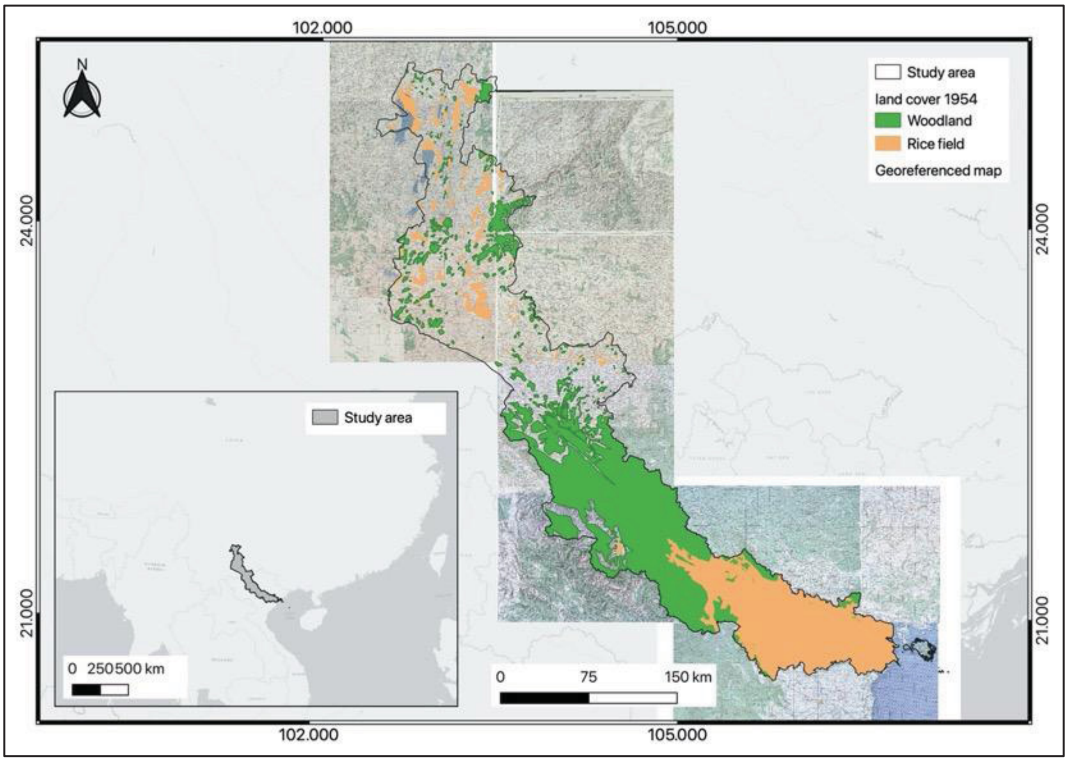


Figure 94, Result of the digitalization of 1954 maps

3.4 Database management

After data classification and preprocessing, there are in all 20 vector layers stored in shapefile format, 19 raster layers in Geotiff (figure 95-96) and thousands of historical images and fieldwork photos in JPG format[127]. As is known, shapefile is a common vector data format developed by ESRI, which is a non-topological format for storing the attribute information through attribute tables. It contains three mandatory binary files, namely the main file (.shp), index file (.shx), and database table (.dbf), as well as other files, such as the projection information (.prj), the code page (.cpg) and so on. However, it still has some disadvantages, such as the limit of storage, poor support for attribute data, non-topological format, data sharing and re-styling problems.

Then, Geotiff is a modification of TIFF (Tagged Image File Format), attached the coordinate system and metadata. It has the similar drawbacks with shapefile. For preserving and managing geospatial data, there are some other advanced formats for a combination of different spatial data, namely spatial database. It is an object-based database facilitates the storing, querying, and manipulating of geographic information, which contains multiple feature classes including points, lines, polygons, network junctions and edges, as well as raster, tables, and references to other tables. There exist some different formats of geodatabase, such as SpatiaLite and GeoPackage, based on the SQL relational database management system (RDMS), and personal geodatabase, file geodatabase in ArcGIS. And PostgreSQL as an object-relational database can also store and analyze spatial data.

[127] A compressed image format standardized by the Joint Photographic Experts Group (JPEG or JPG).

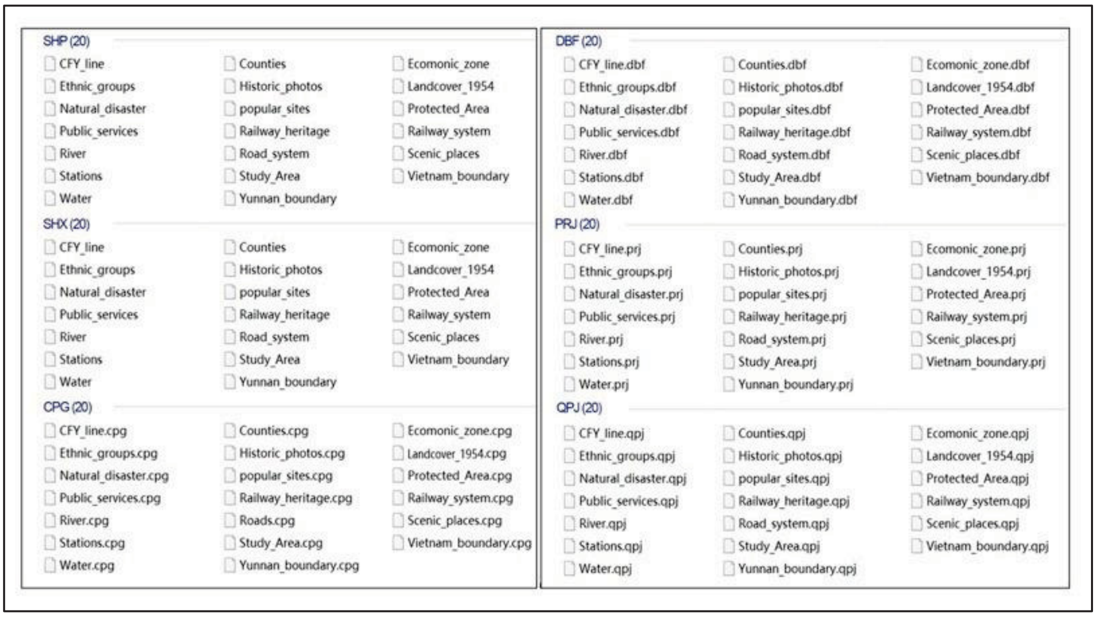
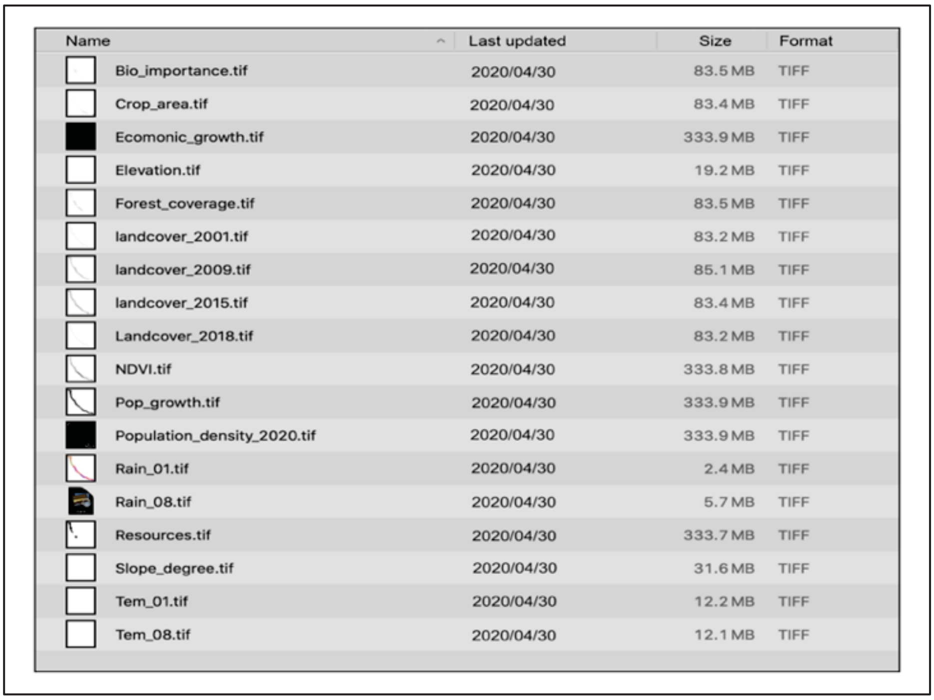


Figure 95, Vector layers overview



Name	Last updated	Size	Format
Bio_importance.tif	2020/04/30	83.5 MB	TIFF
Crop_area.tif	2020/04/30	83.4 MB	TIFF
Ecomonic_growth.tif	2020/04/30	333.9 MB	TIFF
Elevation.tif	2020/04/30	19.2 MB	TIFF
Forest_coverage.tif	2020/04/30	83.5 MB	TIFF
landcover_2001.tif	2020/04/30	83.2 MB	TIFF
landcover_2009.tif	2020/04/30	85.1 MB	TIFF
landcover_2015.tif	2020/04/30	83.4 MB	TIFF
Landcover_2018.tif	2020/04/30	83.2 MB	TIFF
NDVI.tif	2020/04/30	333.8 MB	TIFF
Pop_growth.tif	2020/04/30	333.9 MB	TIFF
Population_density_2020.tif	2020/04/30	333.9 MB	TIFF
Rain_01.tif	2020/04/30	2.4 MB	TIFF
Rain_08.tif	2020/04/30	5.7 MB	TIFF
Resources.tif	2020/04/30	333.7 MB	TIFF
Slope_degree.tif	2020/04/30	31.6 MB	TIFF
Tem_01.tif	2020/04/30	12.2 MB	TIFF
Tem_08.tif	2020/04/30	12.1 MB	TIFF

Figure 96, Raster layers overview

In this research, a young format geodatabase - “GeoPackage” is selected to manage all the vector and raster data together. Defined by the Open Geospatial Consortium “as a geodatabase, GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial information” (OGC, 2020). It is designed to archive and manage the vector data, sets of raster imagery, non-spatial attributes and extensions, as well as spatial indexes. Since its publication in 2014, it has been widely implemented by many major GIS environments such as QGIS, R-language, Python, ESRI, GeoServer, etc. GeoPackage has its own advantages compared with shapefile and Geotiff. It is a self-contained, single-file format, simpler for data migration and sharing process, allowing a maximum storage size of 150 TB and storing map style information.

After reviewing the collected datasets, all the shapefiles and raster are input into a GeoPackage through the “Package Layer” tool provided by QGIS (figure 97). As a result, a GeoPackage database is created with storage size of only 154 MB, which saved a lot of spaces comparing with the original datasets. Each layer in GeoPackage is saved as four spatial index tables (geom, geom_node, geom_parent and geom_rowid) and one attribute table. The output result can be viewed in QGIS by database manager or SQL database application (e.g. Database Brower for SQLite) (figure 98-99). Then, for the vector layers, their layer styles are created and saved in the GeoPackage as a table (layer_styles) attached in the database.

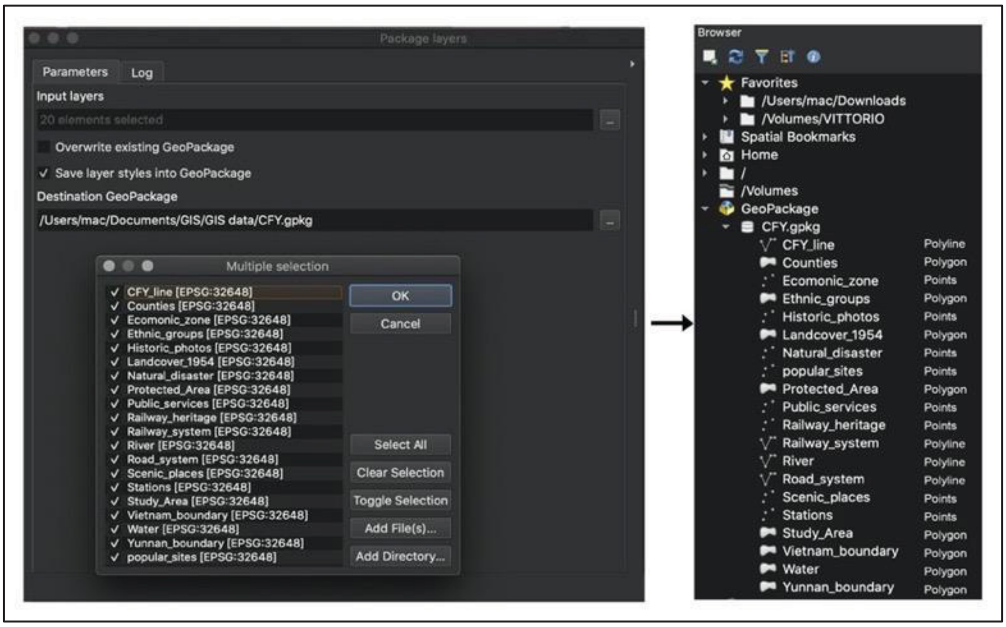


Figure 97, Input layers into GeoPackage by Package layers

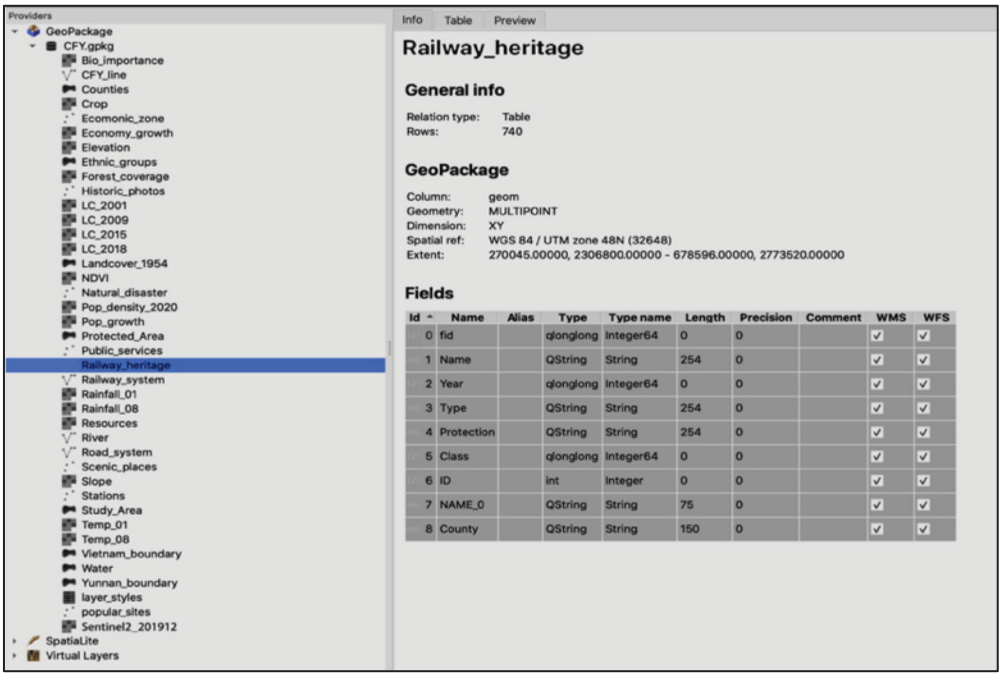


Figure 98, Result of the GeoPackage in QGIS

表: gpkg_contents

	table_name	data_type	identifier	description	last_change	min_x	min_y	max_x	max_y	srs_id
1	layer_styles	attributes	layer_styles		2020-05-04T11...	NULL	NULL	NULL	NULL	0
2	CFY_line	features	CFY_line		2020-05-04T11...	269984.0	2306590.0	678630.0	2773550.0	32648
3	Counties	features	Counties		2020-05-04T11...	243593.0	2227700.0	786603.0	2799150.0	32648
4	Ecomonic_zone	features	Ecomonic_zone		2020-05-04T11...	263579.0	2305030.0	683008.0	2786510.0	32648
5	Ethnic_groups	features	Ethnic_groups		2020-05-04T11...	260151.0	2357540.0	574209.0	2780140.0	32648
6	Historic_photos	features	Historic_photos		2020-05-04T11...	261642.0	2310520.0	665778.0	2785710.0	32648
7	Landcover_1954	features	Landcover_1954		2020-05-04T11...	262706.0	2296660.0	687548.0	2782870.0	32648
8	Natural_disaster	features	Natural_disaster		2020-05-04T11...	287572.0	2468190.0	405117.0	2770020.0	32648
9	Protected_Area	features	Protected_Area		2020-05-04T11...	260032.0	2296660.0	688571.0	2783500.0	32648
10	Public_services	features	Public_services		2020-05-04T11...	262078.0	2301560.0	685251.0	2783150.0	32648
11	Railway_heritage	features	Railway_heritage		2020-05-04T11...	270045.0	2306800.0	678596.0	2773520.0	32648
12	Railway_system	features	Railway_system		2020-05-04T11...	260818.0	2307070.0	674758.0	2779020.0	32648
13	River	features	River		2020-05-04T11...	262389.0	2296680.0	685233.0	2782940.0	32648
14	Road_system	features	Road_system		2020-05-04T11...	260095.0	2296690.0	683808.0	2783100.0	32648
15	Scenic_places	features	Scenic_places		2020-05-04T11...	260415.0	2301540.0	682545.0	2780410.0	32648
16	Stations	features	Stations		2020-05-04T11...	269984.0	2307100.0	675556.0	2773550.0	32648
17	Study_Area	features	Study_Area		2020-05-04T11...	243593.0	2227700.0	786603.0	2799150.0	32648
18	Vietnam_bound...	features	Vietnam_bound...		2020-05-04T11...	206051.0	2132770.0	819041.0	2587030.0	32648
19	Water	features	Water		2020-05-04T11...	261348.0	2298270.0	679075.0	2772030.0	32648
20	Yunnan_boundary	features	Yunnan_boundary		2020-05-04T11...	-261156.0	2341020.0	621589.0	3250220.0	32648
21	popular_sites	features	popular_sites		2020-05-04T11...	260221.0	2298120.0	683959.0	2783340.0	32648
22	Temp_08	2d-gridded-cov...	Temp_08		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
23	Temp_01	2d-gridded-cov...	Temp_01		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
24	Slope	2d-gridded-cov...	Slope		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
25	Resources	2d-gridded-cov...	Resources		2020-05-05T06...	260032.4571	2296665.1502	688321.2377	2783457.5177	32648
26	Rainfall_08	2d-gridded-cov...	Rainfall_08		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
27	Rainfall_01	tiles	Rainfall_01		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
28	Pop_density_20...	2d-gridded-cov...	Pop_density_20...		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
29	Pop_growth	2d-gridded-cov...	Pop_growth		2020-05-05T06...	260032.46	2296707.4941	688571.2302	2783499.8705	32648
30	NDVI	2d-gridded-cov...	NDVI		2020-05-05T06...	260040.0	2296660.0	688540.0	2783460.0	32648
31	LC_2018	tiles	LC_2018		2020-05-05T06...	260425.6759	2297075.5168	687625.6759	2783225.5168	32648
32	LC_2015	tiles	LC_2015		2020-05-05T06...	260032.5123	2296657.5094	688032.5123	2783457.5094	32648
33	LC_2009	tiles	LC_2009		2020-05-05T06...	252582.6798	2295873.9754	688382.6798	2783623.9754	32648
34	LC_2001	tiles	LC_2001		2020-05-05T06...	260425.6759	2297075.5168	687625.6759	2783225.5168	32648
35	Forest_coverage	tiles	Forest_coverage		2020-05-05T06...	260043.67	2296669.4666	688543.67	2783469.4666	32648
36	Elevation	2d-gridded-cov...	Elevation		2020-05-05T06...	260032.4571	2296657.5094	688571.2312	2783499.8761	32648
37	Economy_growth	2d-gridded-cov...	Economy_growth		2020-05-05T06...	260032.46	2296707.4941	688571.2302	2783499.8705	32648
38	Crop	tiles	Crop		2020-05-05T06...	260067.8133	2296808.0057	688317.8133	2783458.0057	32648
39	Bio_importance	tiles	Bio_importance		2020-05-05T07...	260043.67	2296669.4666	688543.67	2783469.4666	32648
40	Sentinel2_201912	tiles	Sentinel2_201912		2020-05-05T14...	243596.9545	2227700.0	786596.9545	2799140.0	32648

Figure 99, GeoPackage shown in the DB Brower for SQLite

Furthermore, the attribute tables in database can be linked through a relationship created by "Joining or Relating" in GIS. With the function of "add relation" in QGIS, when working with the layer's attributes, the related table can be accessed without appending to the layer's attribute table, which facilitate further operations and modifications. Figure 100 shows an example of building relations between the layer "County" and layer "Scenic_places", where the location of scenic places is recorded by the name of the counties, which can be a keyword for the connection. Thus, they can be related through this common field as a one-to-many relationship. Other vector layers containing the information of location counties can be also related to the layer of "Counties". And the layers relate to the CFY line can be connected with each other by their location on the CFY sections.

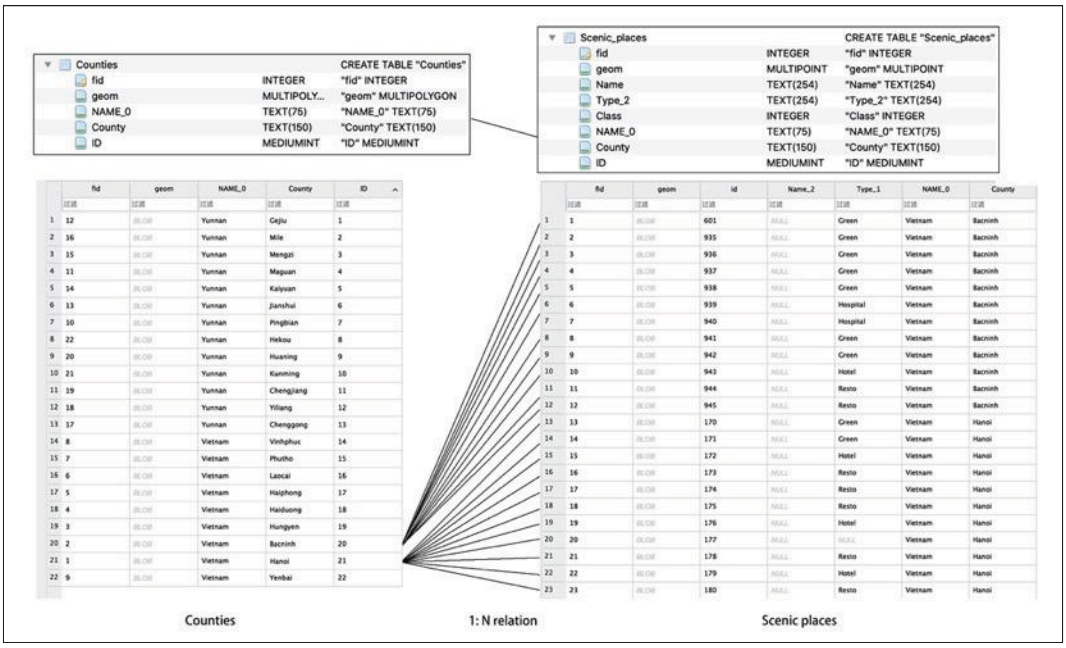


Figure 100, An example of the relations between two tables

In the previous chapter, the data in this research are classified into natural theme and cultural theme. Then, in the database, the relationship of all the vector data tables can be shown in E-R diagram (Entity – Relationship). In general, in an E-R model, it contains the information of "entities, the attributes of these entities, primary key and the relationships". In this study, the tables of vector data are the entities related to CFY. The attributes of each tables are listed in the diagram and their ID is selected as the primary key for each table to make them identifiable. The types of relationship (1:1, 1: N or N: M) are also clarified in the diagram. The following diagram (figure 101) shows these two topics of the database, namely cultural theme data and natural theme data and the relationship among all the tables.

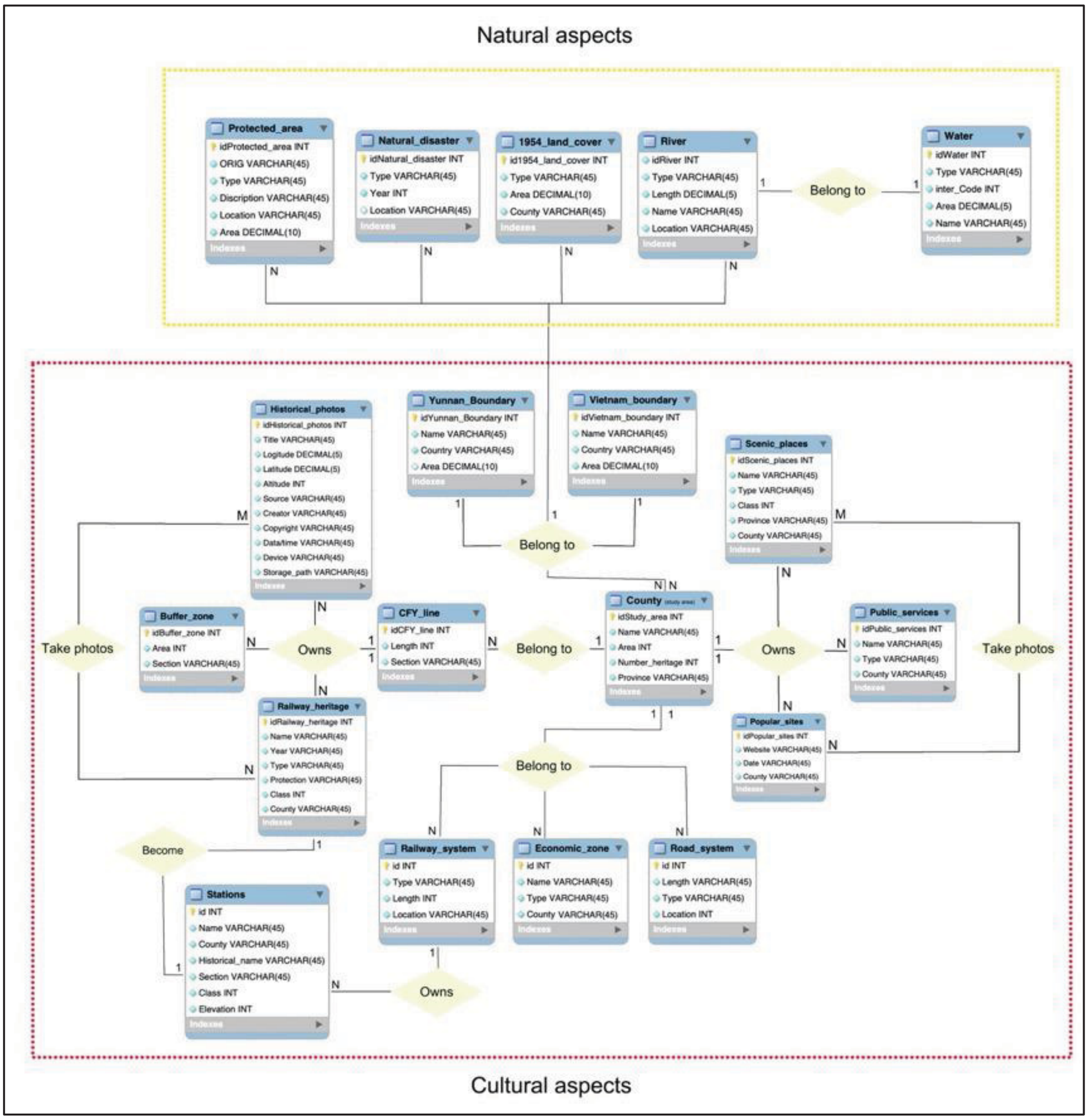


Figure 101, E-R diagram of database

3.5 Building the heritage corridor system

3.5.1 Objectives

To build a heritage corridor system supporting for further spatial analysis, management, touristic activities and other research, there are four objectives set:

1) Effective management. The heritage corridor system designed for CFY is firstly a heritage database, which can link all the various isolated heritage assets and put them in relation with the characteristics of the natural and human environment. It overcomes the shortcomings of the traditional heritage catalog, containing various geospatial layers of heritage elements, including the route itself and present-day and former important sites and structures as the bridges, tunnels and railway stations that may have been abandoned or destroyed during the time, as well as other movable heritages in forms of historical photos that reflecting the railway technology and culture. Based on the heritage database, further heritage classification and evaluation will be made.

2) Reginal coordination. The heritage system contains not only the related railway heritages, but also other resources serving for the heritage redevelopment. In every city/county the CFY passed, the basic touristic information (restaurants, hotels, scenic spots and hospitals) and natural and cultural geographical conditions are also included, which will serve the further tourism planning and touristic activities. According to the comprehensive data, the heritage value of the whole region can be calculated and evaluated, to figure out where are the places with higher values for further heritage and tourism development.

3) Shareability. After the construction of a CFY heritage system, its contents can be shared within a local network or via the Internet so that multiple users will be able to modify and utilize it (WebGIS such as ArcGIS Online). For this reason, such a heritage system needs to be user-friendly from the data acquisition phase to the

mapping one, not only by scholars, specialists, government, different organizations but also by the visitors, railfans or any other who is interested in this railway.

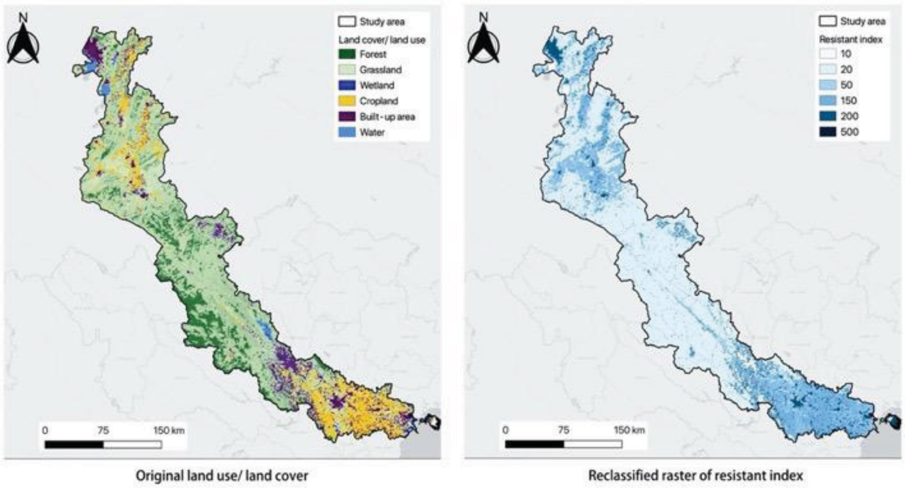
4) Heritage tourism support. This system is also open to tourists for obtaining valuable information before or during their visiting. Based on the Web map application, all useful data in the system can be easily viewed and understood by the visitors, for example, to find the closest location of CFY heritage with the user or preview the photos of the sites to find their interested sites, or viewing the historical photos of CFY without going to the museum or archive.

3.5.2 Define the heritage corridor

The study area is defined in chapter one, containing the cities and counties passed by CFY route in Yunnan and North Vietnam. Based on the concept and meaning of heritage corridor and buffer zone, in order to create the heritage corridor of CFY, the boundary of corridor is mainly considered from the following two perspectives: firstly, the administrative boundary follows the boundary of the study area, namely thirteen counties in Yunnan (Kunming, Yiliang, Chenggong, Chengjiang, Huaning, Kaiyuan, Jianshui, Mengzi, Gebian, Pingbian, Mile, Hekou and Maguan); Nine cities in North Vietnam (Laocai, Haiphong, Haiduong, Hungyen, Yenbai, Bacninh, Phutho, Hanoi and Vinhphuc). Secondly, considering the scope of heritage protection and touristic redevelopment, the physical boundary of the heritage corridor can be classified into the core area and buffer zone.

As is discussed, there are some methodologies used for the creation of buffer zone of heritage corridor, in this study, the MCRM method is applied to build the boundary of CFY heritage corridor, which has been widely used in the landscape ecology and urban planning. Through constructing the nodes of activities, corridors and resistance surface, it aims to optimize the connectivity of ecosystem and urban ecological network (Chen, et al., 2020)

According to previous studies (Yu, et al, 2005; Yuan & Zhang., 2014; Zhan & Guo, 2015), different land use/ land cover has various resistance for the heritage tourism activities. The resistance index can be given between 10-500 by the different type of land use, among which the forest coverage has the smallest resistance, and road systems has the highest resistance for heritage tourism. The reclassification rule is set by their value of resistance (figure 102). Based on the reclassified resistant value and the line of CFY as the source nodes of heritage activities, a raster of cost distance is created through the tool of “cost distance” in GIS (figure 103), showing the suitability value in the study area for developing heritage tourism. Measured on the map, the core area for the heritage tourism activities can be defined within a distance of one km from the CFY line, and the radius of buffer zone for heritage protection can be set as ten km from the CFY line.



Name	Original value	Reclassified value
Forest	1-5	10
Water/ wetland	17, 11	20
Grassland	10	100
Cropland	12	150
Built-up area	13	200
Road system		500

Rule of reclassification

Figure 102, Process of creating cost distance

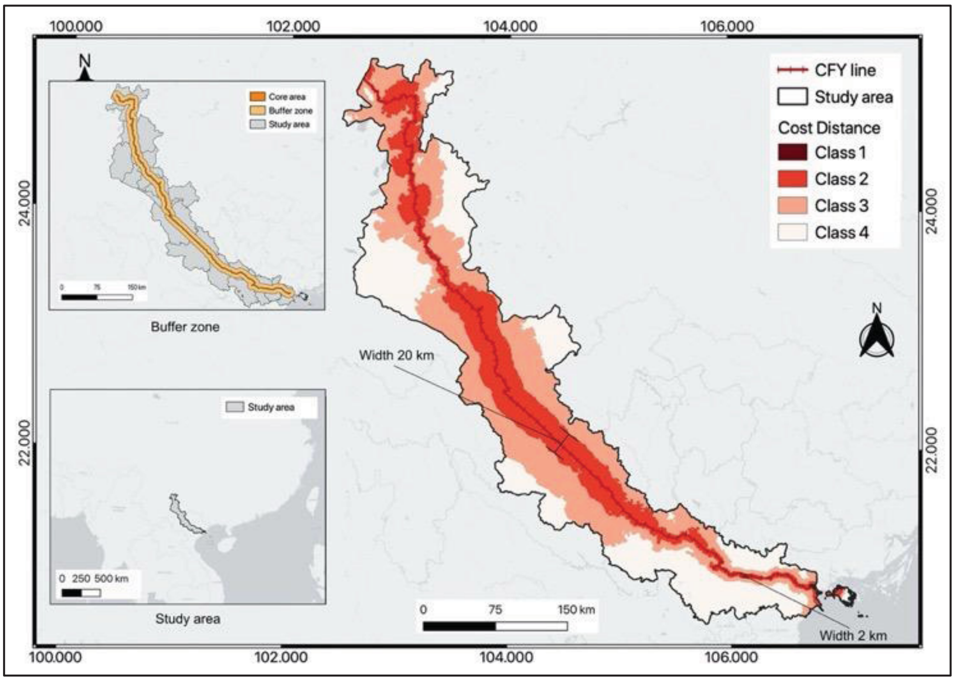


Figure 103, Cost distance based on the resistance index for heritage tourism

Thus, as is shown in figure 103, the heritage corridor is built with two levels - core area (a radius of 1 km and a width of 2 km) and buffer zone (a radius of 10 km and a width of 20 km). The rest of the study area is considered as a landscape context for the heritage corridor. Further analysis will focus mainly within the buffer zone of CFY heritage corridor. According to the administrative divisions, the heritage corridor is also classified into 21 parts, and the area of each part in heritage corridor is counted and shown in figure 104. In this way, the management authority and responsibility of each buffer zone can be clarified.

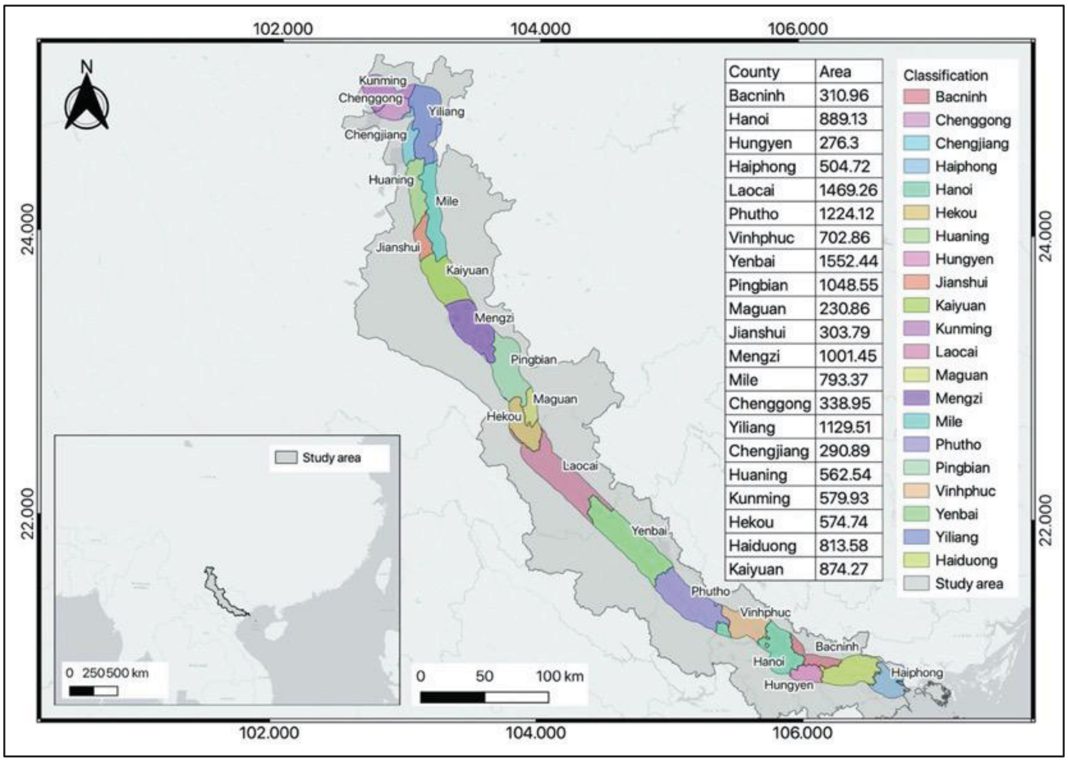


Figure 104, Classification of the corridor

3.5.3 Define the heritage resources

The heritage system expands the meaning of CFY as not only an isolated railway. On basis of the characteristics of history, culture and geographic context of CFY, the heritage resources within the heritage corridor are composed as follows: physical railway remains, movable railway heritages, the route of CFY, other touristic resources, and the important ecosystems in the region (figure 105).

1) The physical railway remains include railway stations, bridges, signs, tunnels, railway facilities, public services buildings and living buildings of the railway company, communications facilities.
2) The movable heritages reflect the railway culture and history, including the related documents (historical photos and maps in archive), and relics conserved in the museum such as the railway instruments, signals, signs, money, rail, and railway tickets systemized by the Yunnan railway museum.
3) Other touristic resources in this area include urban parks, scenic resorts, mounts and historical buildings, historical cities/towns and ethnic villages.
4) The important ecosystems in this area are concluded as freshwater river, freshwater swamp, limestone, mangrove, nature reserve, rainforest, green corridor and key biodiversity areas.
5) To support railway tourism, the related public services in this heritage corridor system are also involved, including the restaurants, hotels and hospitals.

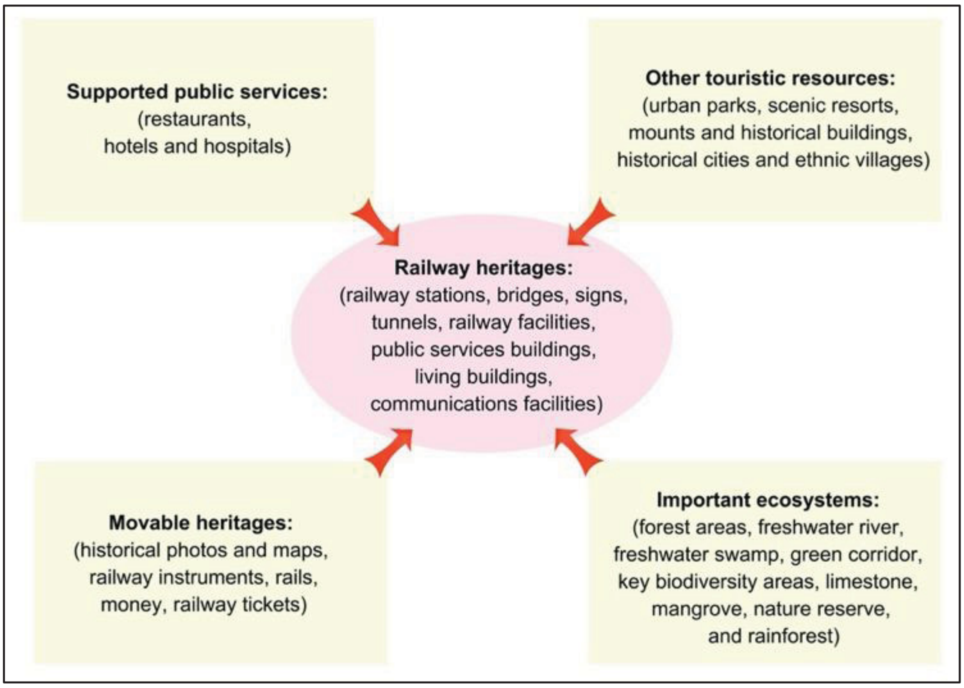


Figure 105, Heritage resources classification

3.5.4 Heritage corridor evaluation

After the definition of heritage corridor and the related heritage resources. The heritage value of the whole area in the corridor can be assessed by various indicators. Through relevant documentation research, field investigations and comparative studies, various aspects and dimensions of heritage need to be assessed to understand accurately the value behind a heritage, which is the foundation and guidance for heritage protection, conservation and development. Based on the quantified value of heritage, further quantitative and qualitative analysis can be done to identify its class of importance and to formulate the measures and plans for its future protection and development.

Cultural heritage has been evaluated by indicators since the 1990s with diverse assessment tools (Agnew & Demas 2002; Jin, 2012), which can be generally classified into four main groups: historical value, artistic value, scientific value and additional values in different cases (Song, et al., 2014). Comparing with cultural heritage, an industrial heritage emphasizes more its scientific and technological value. TICCIH develops a framework for the assessment of industrial heritage, which focuses on "social value for the records of the lives of ordinary labors, provided the sense of identity; technological and scientific value in the history of manufacturing, engineering, construction; aesthetic value for the quality of its architecture, design or planning." (TICCIH, 2003). Each country has its own regulations to follow for the evaluation process, for example, the IH evaluation system in China is explained in table 16 (Liu & Li, 2006) (table, 16).

Table 16, Evaluation system for the Chinese industrial heritage

As for railway heritage, different value criteria are identified by scholars, especially for the evaluation of CER in China (Gao & Shao, 2018). But most of these evaluation systems for railway heritage are qualitative and descriptive. Jiang et al. (2019) firstly proposed and classified the indicators for Chinese railway heritage into four types, which include:

1) Technical value, namely the physical relics elements of railway and year of railway construction;

2) Historical value: degree of retention of function and the track, number of railway remains, historical changes of the route, degree of abandonment, and the number of important historical events;

3) Cultural value: related colonial age, number of the colonial countries, involved ethnic minorities, and foreign participation in the construction process;

4) Social value: number of provinces it served, total number of railway stations, its impact on social productivity and development, the historic and current needs of the railway transportation, public perception of railway heritage, and the annual freight volume and passenger transport at the time of construction.

Then, Delphi expert method combined with Analytic Hierarchy Process (AHP) is the useful tool most discussed to identify the heritage factors (Turskis, et al., 2013). The AHP method assistants the decision-making process, which analyzes and solves the problem through multiple layers, including the essence of goal, influencing factors, solution and their relationship. The Delphi method also called the Expert Judgment System, takes the opinions of experts into consideration, used for avoiding subjective evaluations and saving time for numerous questionnaires, which is applied in the evaluation of landscape quality (Li, 2005; He, 2013), landscape resources (Chen, et al., 2009), eco-environment quality (Xiong, et, al., 2007), heritage management (Kutut, et al., 2014; Morano, 2016).

Therefore, in the heritage evaluation of CFY, it integrates AHP, Delphi Method and GIS as a spatial integrated assessment method (Girard & De Toro, 2007; Li, 2014), to establish a hierarchy model of the evaluation system in the comprehensive conservation and development of CFY heritage corridor. The process of the whole evaluation is shown in figure 106, including the selection of indicators, establishment of the hierarchical framework, reclassification the value of indicators, decision of the weights of indicators, overlay the indicators in GIS and get the final result of heritage value.

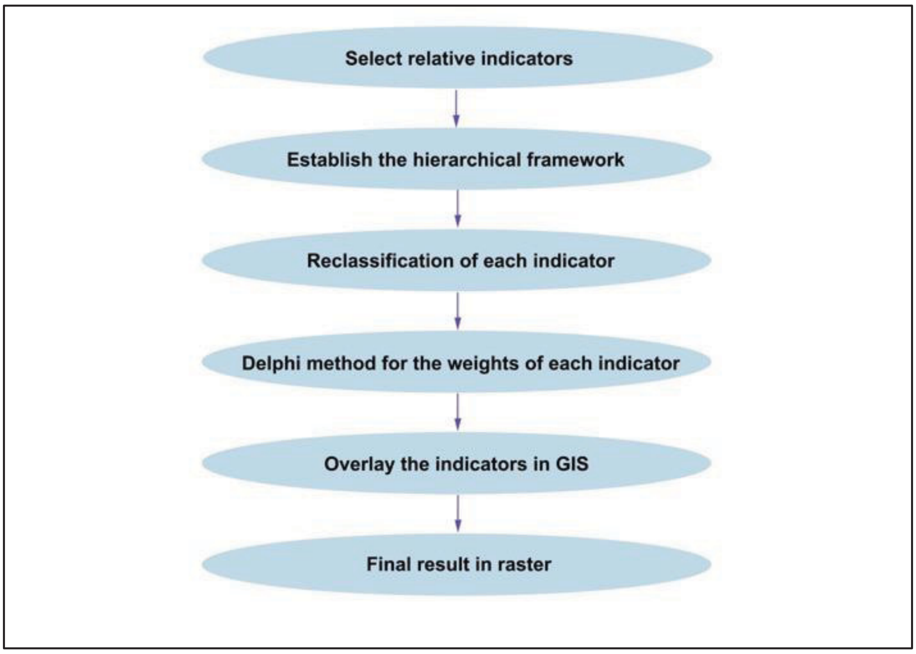


Figure 106, Process of the heritage evaluation

The first step is to review other related and similar research (Brunsden, 1979; Tudor, 2019; Martín et al, 2016; Ying et al, 2007; Yu et al, 2011; Tveit et al, 2007; Jiang et al, 2019). Afterwards, the criteria of indicators are specified as a result within ecology, tourism and heritage protection in correspondence with the main values of CFY heritages. The indicators applied in this research are specified into five groups: landscape (B1), technology (B2), ecology (B3), social-culture (B4) and tourism (B5), which can be also regarded as five topics of the CFY heritage corridor. Then, each indicator is further explained into three indexes, referenced by previous research (table 17):

1) Landscape indicator: scenic spots (C1), visibility (C2) and stream density (C3);

2) Ecology indicator: vegetation index (C4), naturalness (C5) and biodiversity (C6);

3) Technology indicator: historical richness (C7), engineering difficulty (C8) and climate suitability (C9);
4) Social culture indicator: population density (C10), cultural density (C11) and economic growth (C12);
5) Tourism indicator: touristic services (C13), accessibility (C14) and popularity (C15)

Table 17, Criteria for the evaluation system for CFY heritage

To check the correlation coefficient of selected indexes, the “CORREL function” is used to get the Pearson product-moment correlation coefficient (r). The value of “r” is usually between -1 and 1. When the obtained correlation coefficient amounted to higher than 0.8, one of the two indices needs to be reconsidered and replaced. The Pearson correlation coefficient is calculated as follows by the formula (x and y indicate the sample value of the indexes):

$$r = \text{Correl}(X, Y) = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}}$$

In the study area, the railway stations are selected as the sample points to get the value from the raster. There are in all 85 stations along the route as the sample. The result of calculation is shown in table 18, and all the correlations between each two indexes are qualified to be smaller than 0.8.

Table 18, Correlations for each pair of indexes

Then, for the next step, according to the rule of reclassification of every index (table 19), each raster layer of the index is reclassified into five classes with the score 1-5 (1: lower value and 5: higher value), among which the value indicates a comparative result within the study area. The figure 107 shows an example by using the reclassify tool in QGIS for the reclassification of the index of NDVI, whose original value was between -1 to 1, and then it is reclassified into the value between 1-5.

Table 19, Explanation of each index

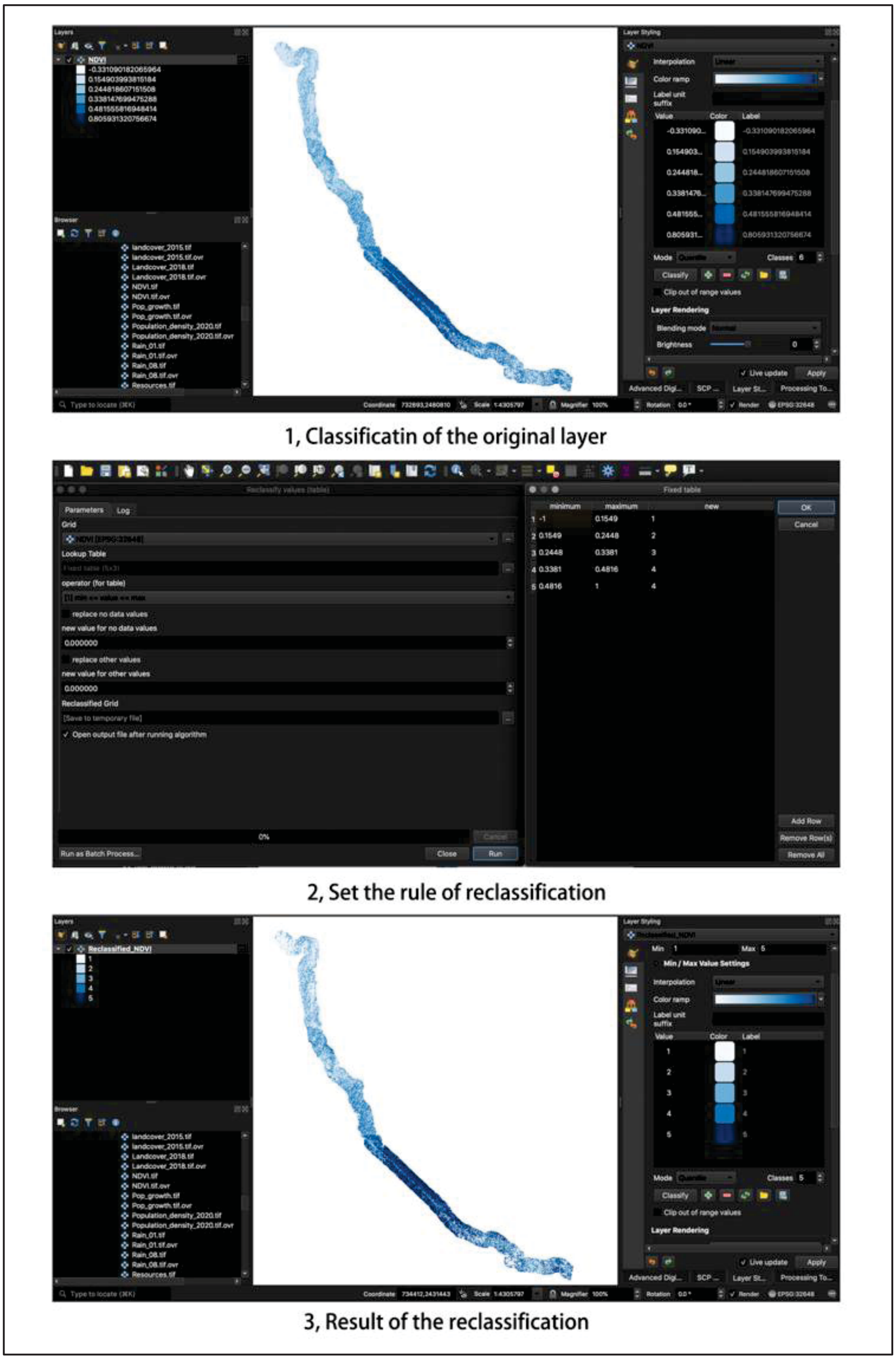


Figure 107, Reclassification of the index layer

After the reclassification of each index, in order to figure out the weight of each index for the evaluation, the Delphi method is introduced. There are in all five experts[128] invited to do a questionnaire (appendix 1), to compare the relative importance of each two indexes, giving them value according to the rule defined in table 20. After the questionnaire and discussion with these experts, the importance comparison between every two indexes from the same indicator is obtained, shown in table 21.

Table 20, Relative importance comparison between each two indexes

Table 21, Result of questionnaire for expert

Known the importance comparison for each two indexes, the model of matrix needs to be made to calculate the weight of each index with the help of the application "Yaahp"[129]. The process of calculation through the building of comparison matrix and result of weight of every index in Yaahp is shown in figure 108. The consistency of the result is also checked, which needs to be smaller than 0.1. And the result of the weight calculation is as followed in table 22:

Table 22, Weight of each index

[128] The five experts are from historical, landscape, anthropological, tourism and GIS studies.

[129] It is a software assisting AHP and fuzzy-AHP evaluation method, to support the decision-making process, and providing helps in model construction, calculation and analysis. Website: http://www.metadecsn.com/product/

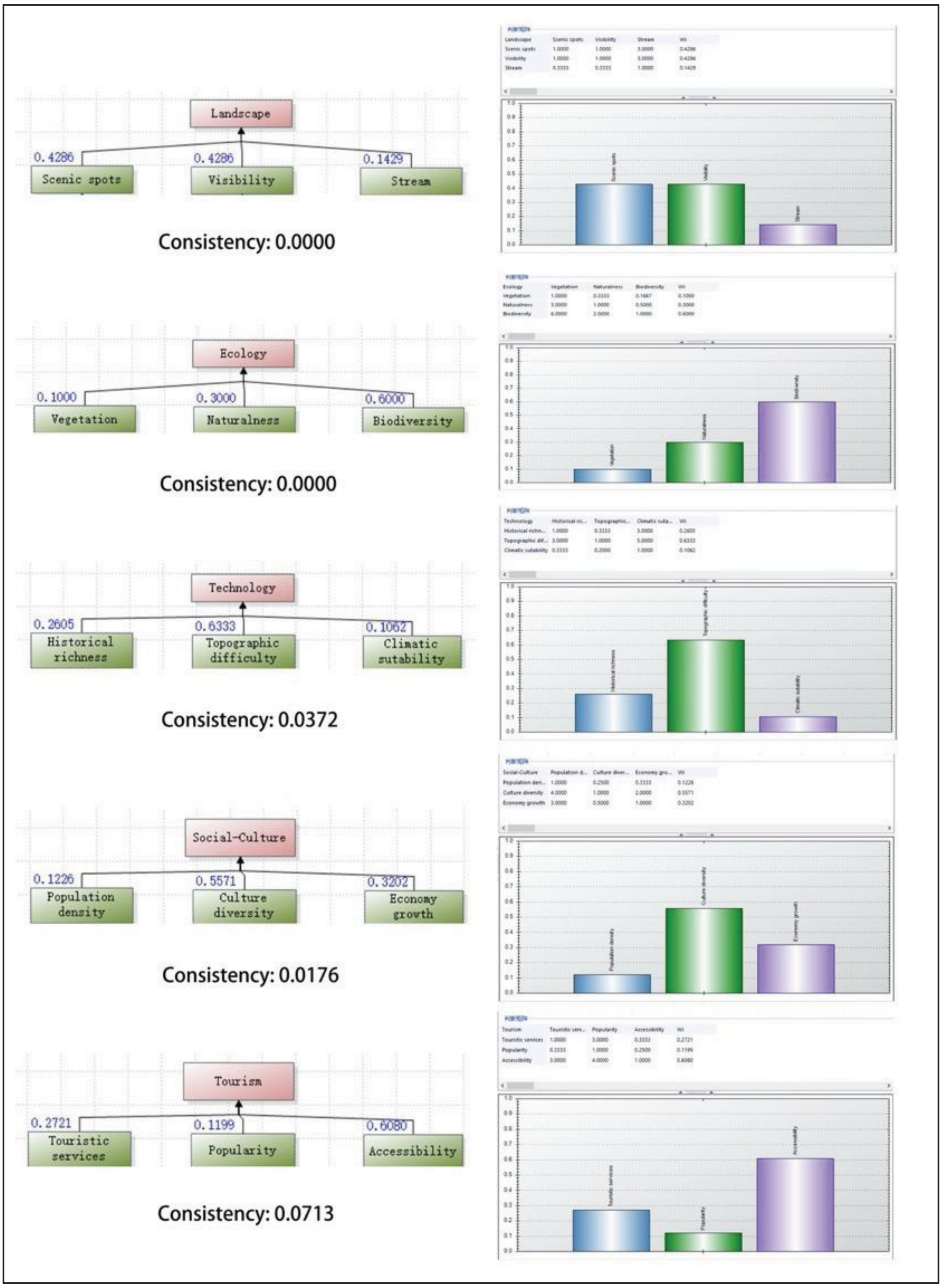


Figure 108, The weight of every index calculated by Yaahp

At last, the heritage value can be calculated by overlaying the raster layer of these indexes. The raster calculator in QGIS is used to overlay all the raster layers with their weighs by the following formula (figure 109):

Heritage value = (scenic spots * 0.4286 + visibility * 0.4286 + stream density * 0.1429)+ (NDVI * 0.1 + naturalness * 0.3 + biodiversity * 0.6) + (historical richness * 0.2605 + engineering difficulty * 0.6333 + climatic suitability * 0.1062) + (population density * 0.1226 + cultural diversity * 0.5571 + economy growth * 0.3202) + (touristic services * 0.2721 + popularity * 0.1199 + accessibility * 0.6080).

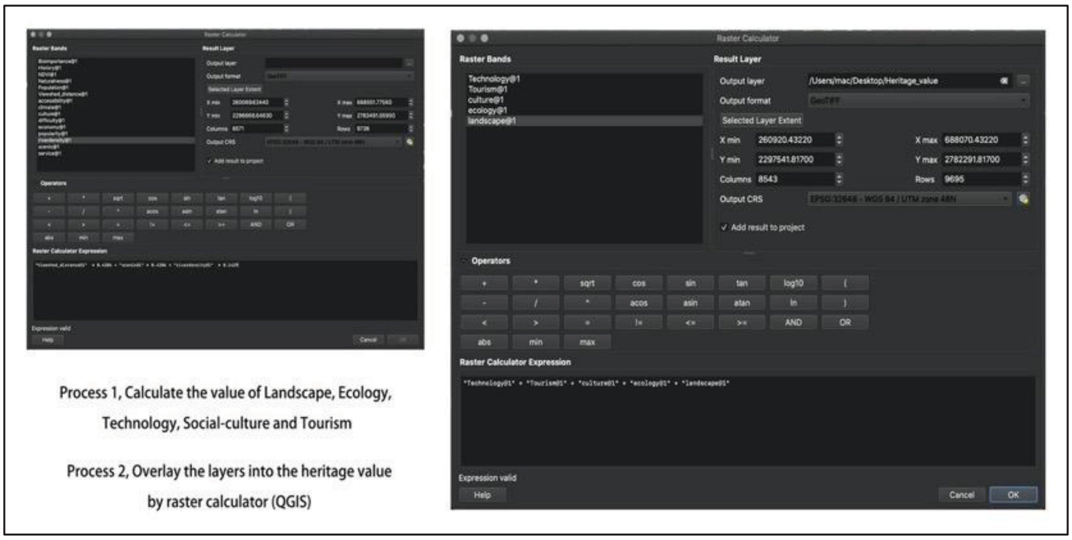


Figure 109, Process of calculating heritage value

The result of heritage value in the heritage corridor is as displayed in figure 110. Overlaid by fiver layers, the total score of heritage value is 30 in the corridor. Then, the heritage value is classified into five classes (1-5), showing the areas with a higher heritage value (red to orange) to a lower value (yellow to white), according to the classification type as “quantile”, and the interpolation mode as “discrete”:

Class one: 0 - 8.6;   Class two: 8.6 - 10.0;

Class three: 10.0 - 11.3;   Class four: 11.3 - 12.9;   Class five: 12.9 - 30

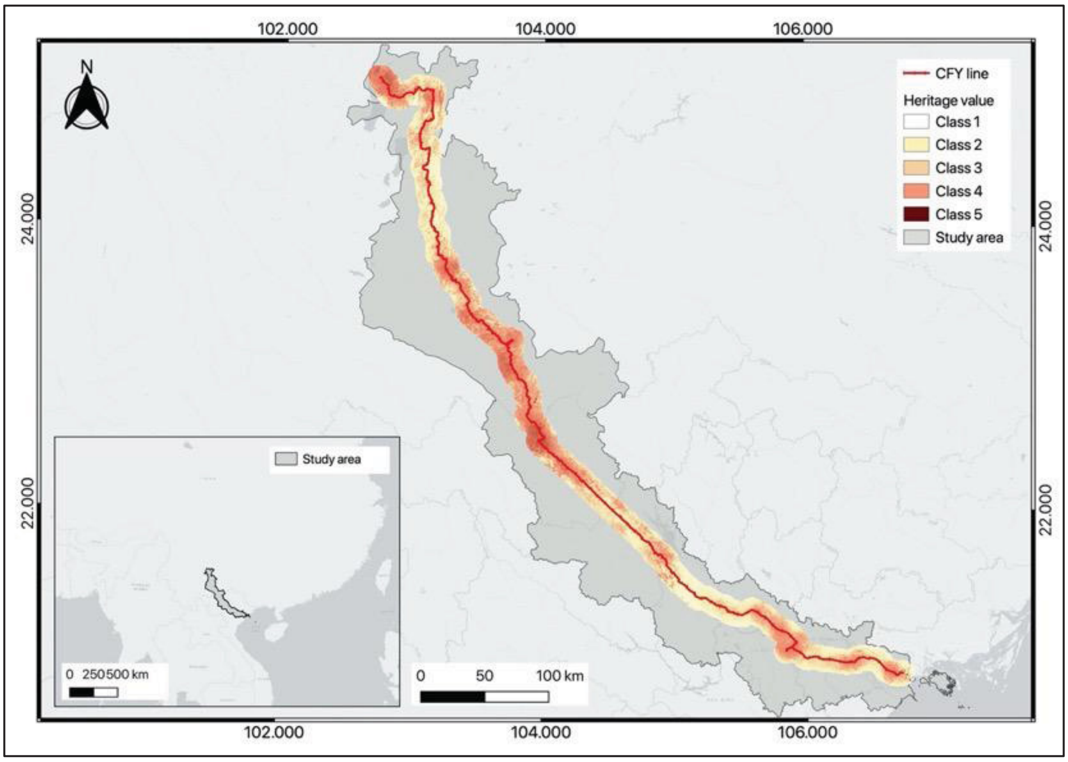


Figure 110, The result the heritage value

3.5.5 Spatial pattern of heritage corridor

Based on the heritage value in the heritage corridor, further spatial pattern of the heritage system can be clarified and defined. To figure out the heritage value in each administrative body, the value in raster is extracted to the vector layer of cities/counties in the study area. The zonal statistics tool in QGIS is utilized, calculated for each county based on the mean value of the heritage value in raster. The figure 111 indicates that Kunming, Pingbian and Hekou are the three cities with the highest heritage value in study area. Then, Chenggong, Yiliang, Laocai and Mengzi have with a medium value; Chenggong, Yiliang, Gejiu, Maguan, Kaiyuan, Haiduong, Yenbai, Hanoi and Haiphong with a lower value.

According to this classification, the core of corridor can be defined as eight with three classes (class 1-3: less important – more important)[130]. And the cores are connected by the CFY line as a corridor. Thus, the structure of heritages corridor can be organized as eight cores with one line (figure 112). The heritage value within the study area is reflected and overlaid by five aspects: landscape, technology, ecology, social-culture and tourism, namely it is a comprehensive value of the whole study area. Then, the values of these five aspects can be separated to show the thematic maps based on the five topics, which is discussed in the next chapter.

[130] The adjacent counties with same value are classified as one core.

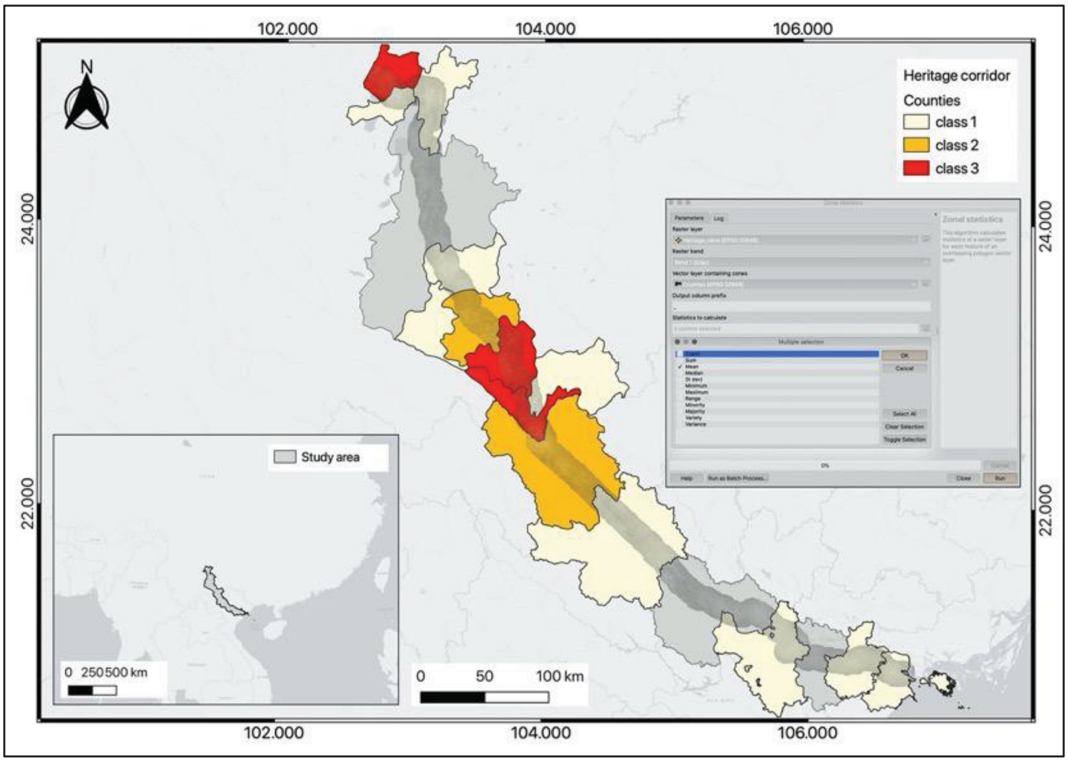


Figure 111, Zonal statistic of the heritage value

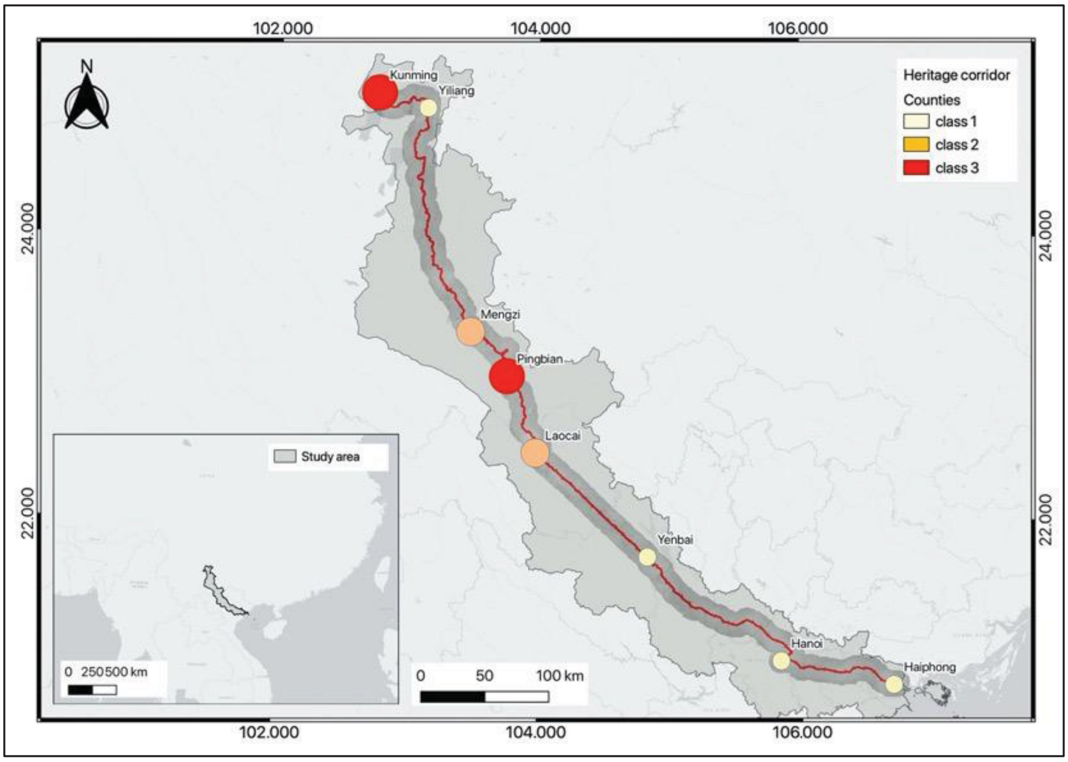


Figure 112, Heritage core of the corridor

CHAPTER 4. RESULTS

From previous chapters, the CFY heritage system is created based on various topic of vector and raster data; The heritage value is assessed quantitatively, and the structure of heritage corridor is built based on the heritage value in each county in study area. Then, more functions and applications can be fulfilled according to the data in the heritage database. As a result, the functions of basic mapping, heritage classification, heritage visualization, analysis of geo-historical changes and tourism-supported application are developed as results of this research.

4.1 Basic mapping

Firstly, the basic function of mapping can be carried out to show the general situation in the study area or in the heritage corridor, for example, the elevation changing, distribution of river, road system, and the heritage sites. The whole CFY line is divided into four sections (Kunming – Kaiyuan – Hekou – Hanoi - Haiphong). Then, the basic geographic data are also uploaded on ArcGIS online including the layers of railway stations, CFY line, river, road system and the study area with the topographic map as background.

According to the five topics of the CFY heritage corridor, namely: landscape, ecology, technology, social-culture and tourism, thematic maps can be made in accordance with these heritage topics in ArcGIS online map (figure 113). In each map, an average value in each city/ county is extracted from the raster layer, showing the topic value changes in the study area. The results can be viewed online though the sites attached below:

1) General map:
https://www.arcgis.com/apps/InteractiveLegend/index.html?appid=4d38d9c2142142fd9e58a5c10c76d191

2) Technological theme:

https://www.arcgis.com/home/item.html?id=ea8e2ce19ea94890aba30dc4680dcfc8

3) Ecological theme:

https://www.arcgis.com/home/item.html?id=ea0329129d8d485c85184b577941cc7b

4) Landscape theme:

https://www.arcgis.com/home/item.html?id=9cb54066ccad4b9495656961309e9a02

5) Social-culture theme:

https://www.arcgis.com/home/item.html?id=f51dc7b6afbc42edb8efbefda8e4517b

6) Tourism theme:

https://www.arcgis.com/home/item.html?id=fc409fa08d5e49af9a471b2a596aab17

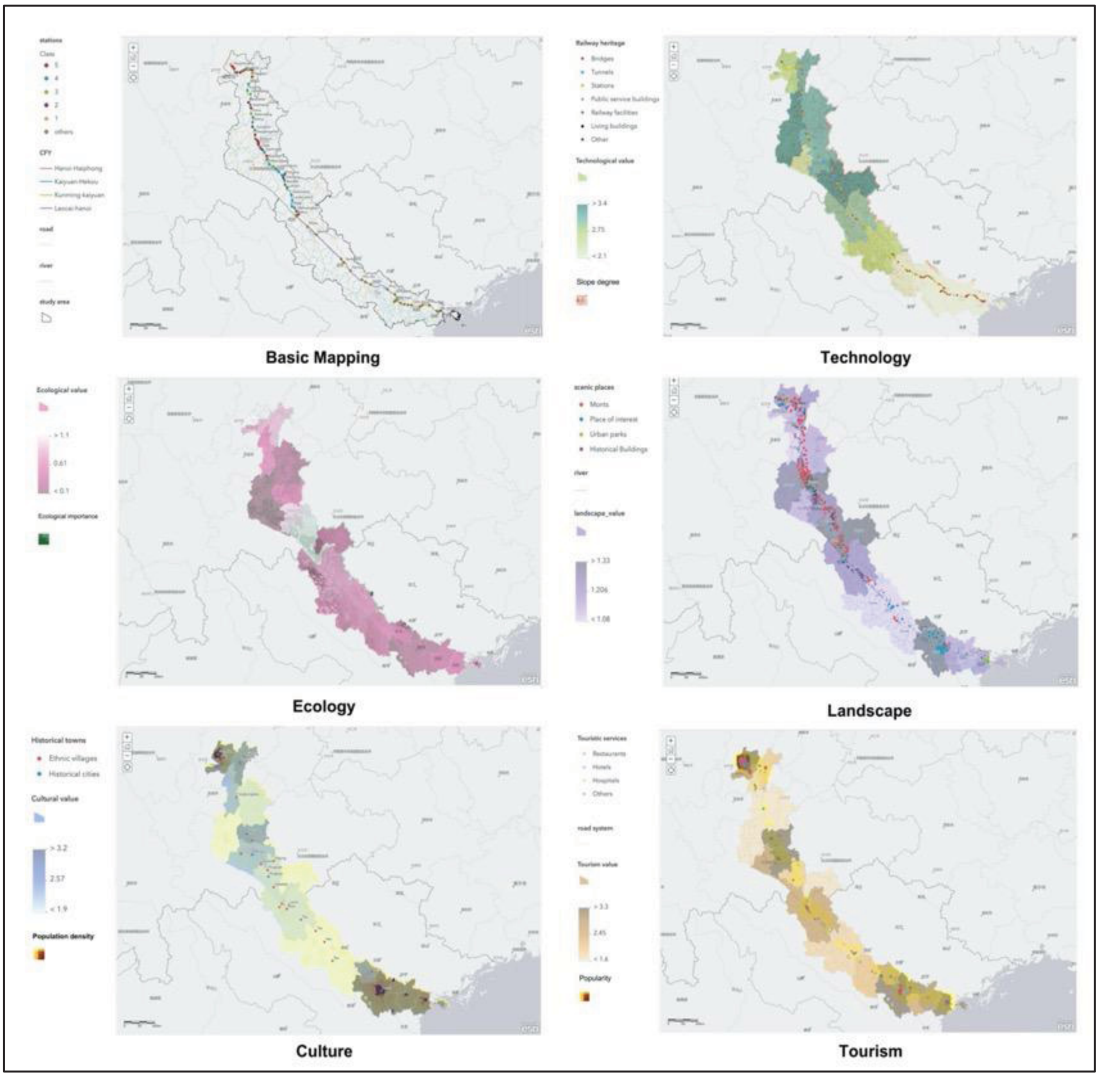


Figure 113, Output of thematic mapping in ArcGIS online

4.2 Railway heritage classification

The heritage resources in CFY heritage corridor are composed by physical railway remains, movable railway heritages, the route of CFY, other touristic resources, and the important ecosystems in the region. The central part of the railway heritage includes the physical railway remains and movable railway heritages. In the CFY database, it involves 515 sites of railway stations, tunnels, bridges, living buildings and public serving buildings according to the site survey of Yunnan and the online map. Figure 114 shows the overall distribution of the physical railway remains. An atlas is also made to show the detail of the heritages in each county with a scale of 1: 20000, and each section is named by its location within the city/county (figure 115).

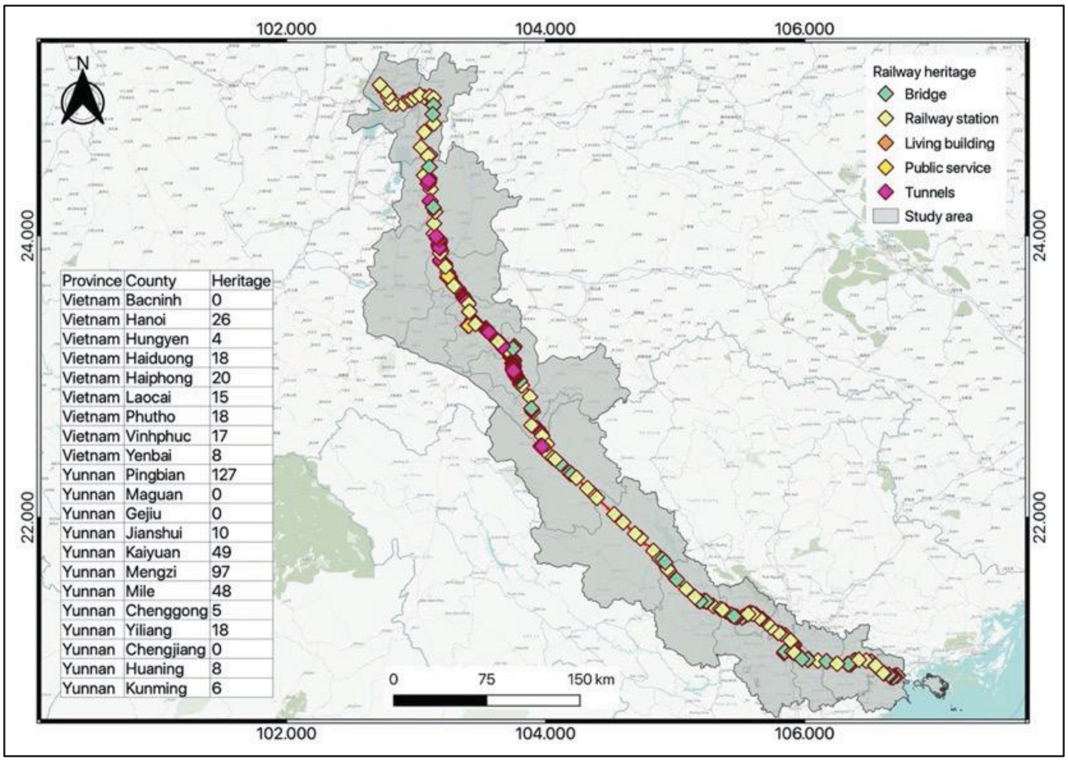


Figure 114, distribution of physical railway heritages

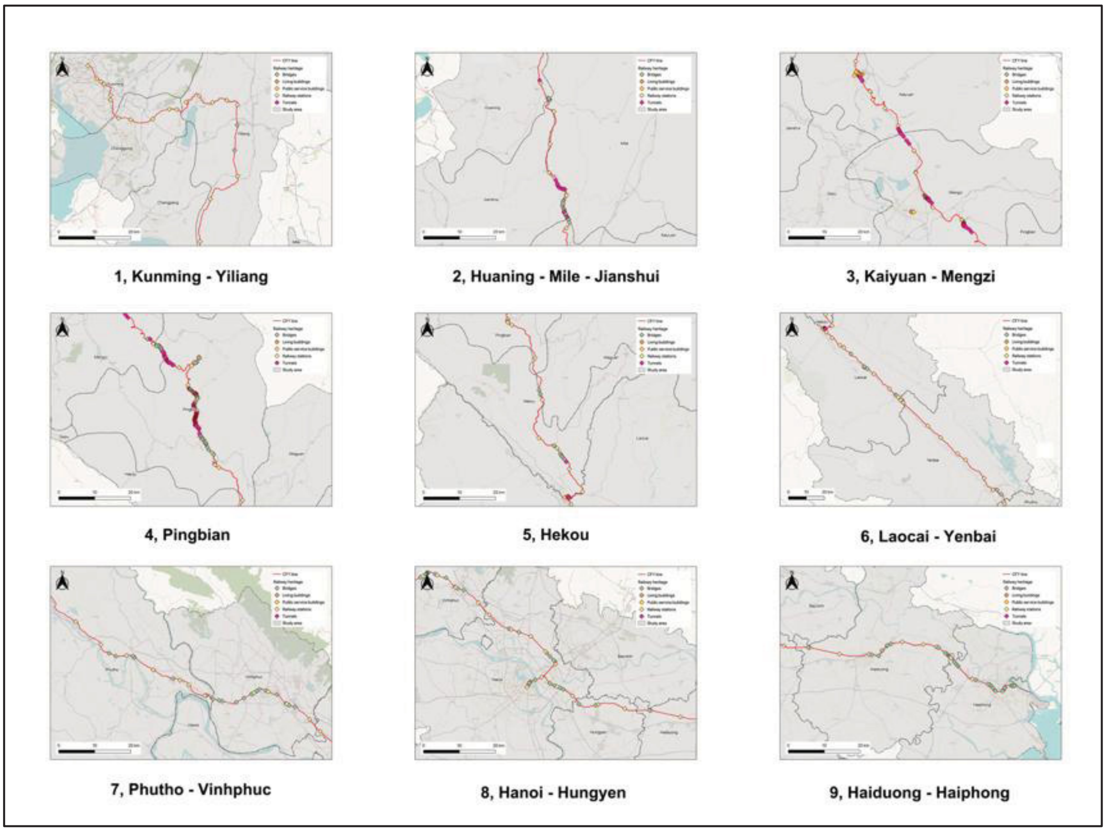


Figure 115, Atlas of the railway heritage in each county

For the movable railway heritages, the Yunnan railway museum has collected 261 pieces of locomotives, measuring tools, rails, signals, signs, tickets and bills, historical documents and records. In this research, there are in all 134 photos of these movable heritages obtained from the published book and imported into the database. Thus, the movable railway heritages of CFY is consisted of these photos of the relics in museum as well as the historical photos and maps, in all 1107 photos. Their distribution and classification are shown in figure 116, with the frames showing the details in Kunming and Pingbian. However, there are few historical photos collected for the area of North Vietnam, thus, this area is not shown in the map.

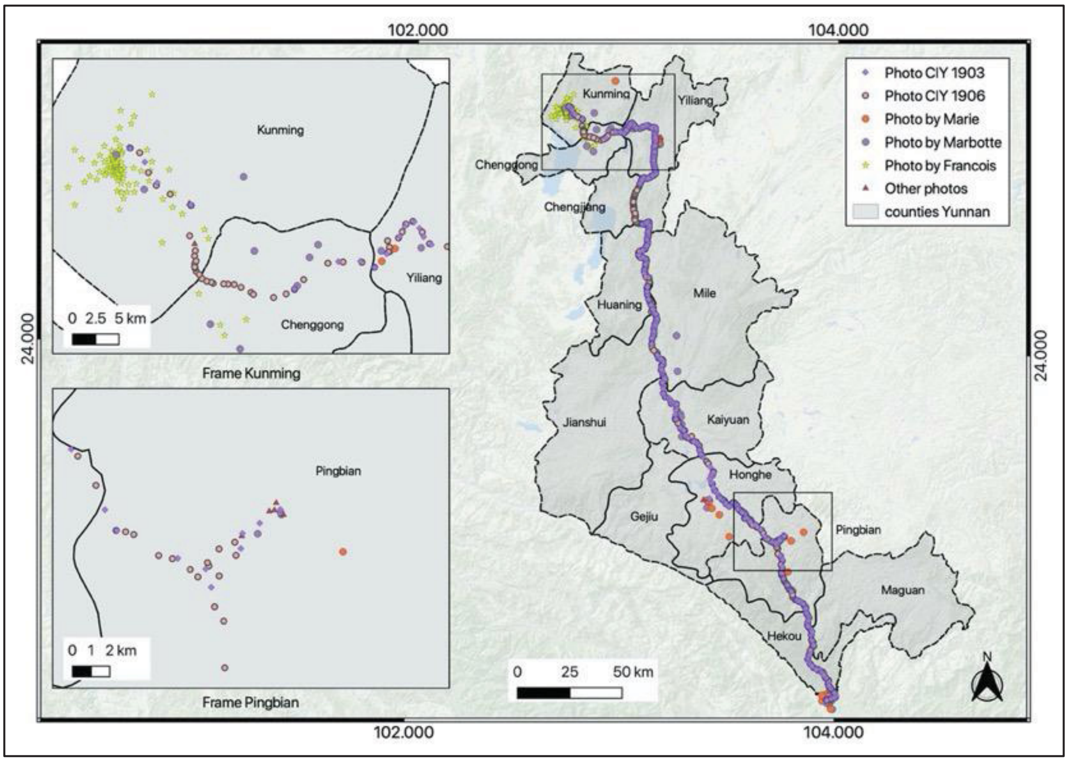


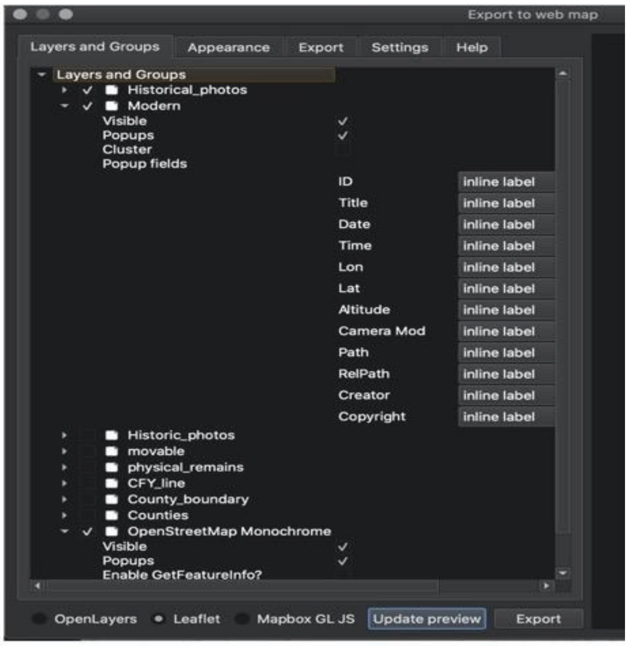
Figure 116, distribution and classification of movable railway heritages

4.3 Heritage visualization

In order to create a user-friendly environment to view the core data in the database, especially the data of railway heritages and historical photos, the WebGIS is applied to visualize the heritage data. WebGIS has been developed rapidly since the 1990s. It is a pattern or approach for implementing a modern GIS by combining Internet technology with GIS, to realize the storage, display, analysis and output of spatial data on the internet. It's powered by web services, which deliver data and capabilities and connect components. WebGIS is also an integrated globalized client/server network system, as an optimal solution for GIS interoperability and decision-making support. Users can directly access GIS data through a Web browser and realize the spatial functions, data retrieval and query, thematic map making, data editing and modification. WebGIS has its advantages over the traditional geographic information systems, for example, interactive maps and data on cross-platforms (internet browsers, tablets, mobile phones, etc.), rapid information release, lower costs, timely data update, simple and global access and rich usability, etc. A general workflow of WebGIS is shown in figure 117.

Figure 117, A general workflow of WebGIS

The function "gis2web"[131] in QGIS is utilized to input the data into webpage (figure 118). Gis2web is designed with various functionalities, for example, "extract geographic information from GIS database to the Internet; transfer information from GIS server to a gis2web server; parse the information from GIS servers and convert it to the formats in WWW servers; access statistics can be used to determine the type and quantity of information to store with frequently referenced information maintained locally and other information retrieved on demand to minimize storage space and network traffic; provide and display information on the webpage according to the requests of internet users" (Meng et al., 1997). The output data by Gis2web contain a complete set of HTML, CSS and JavaScript. Parts of the web codes are recoded to give more functions to the Web service.



[131] Qgis2web is a plugin for generating web map from QGIS, as OpenLayers, Leaflet, or Mapbox. It can replicate many aspects (layer style, extent, etc.) of the original layer. And no server-side software is required. It is a bridge between GIS software, datasets and the internet.

Figure 118, The tool of Gis2web in QGIS

The Web map of CFY heritage contains all the historical photos and fieldwork photos taken by the author. The webpage is designed and divided into five sections: navigation with the related links, title of the web, examples of showing some photos, content of the map and the copyright (figure 119). For every single point on the Web map, a photo is attached. Then, the Webpage has the basic functions of zoom in/out, to check the detail of the location of photo sites, the tool to measure the distance between two points, and the search engine to find a place on the map (figure 120). For the detail of every photo, the metadata includes the title, date and time, longitude and latitude, altitude, camera mod, type of the photo (modern or historical), author and its copyright (figure 121). All the data of webpage was uploaded to the internet, any user interested in the heritage sites of CFY can download it and then implement the full function of this Webpage. Through this webpage, the user can easily view the data of CFY heritages, including the historical photos, modern photos and the metadata of these photos. Thus, the visitors can preview the landscape of the heritage sites, and the scholars can take use of these historical photos for further studies[132].

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[132] The original data and codes are shared online by GitHub: https://vittoriosskk.github.io/Yunnan_Vietnam/

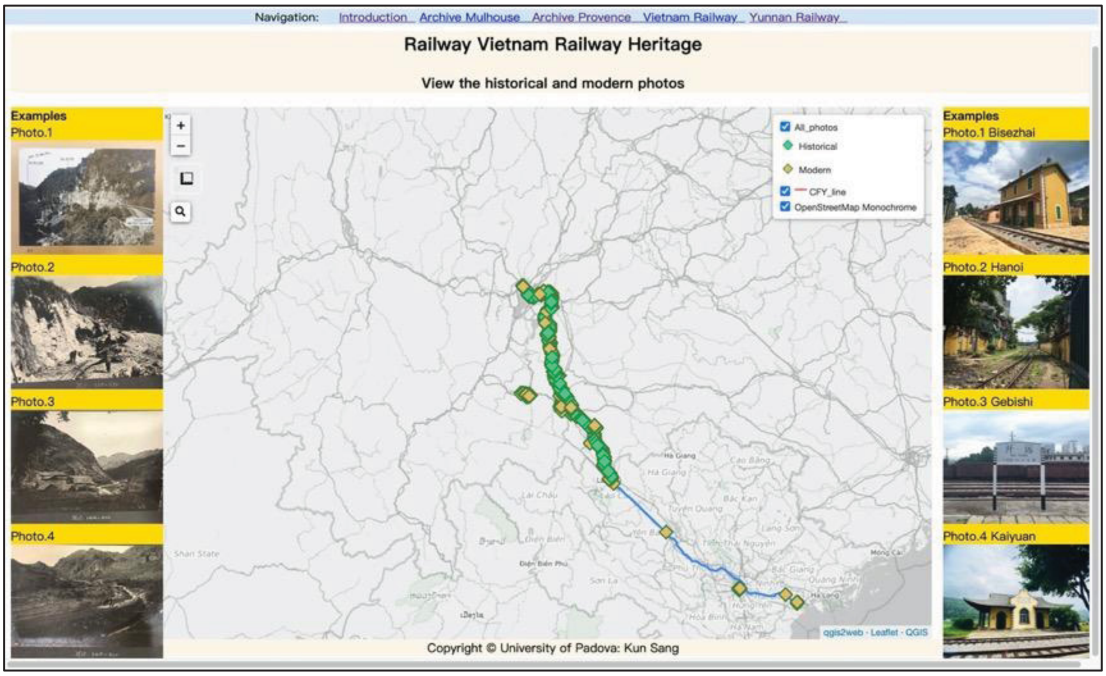

Figure 119, Overview of the designed Webpage

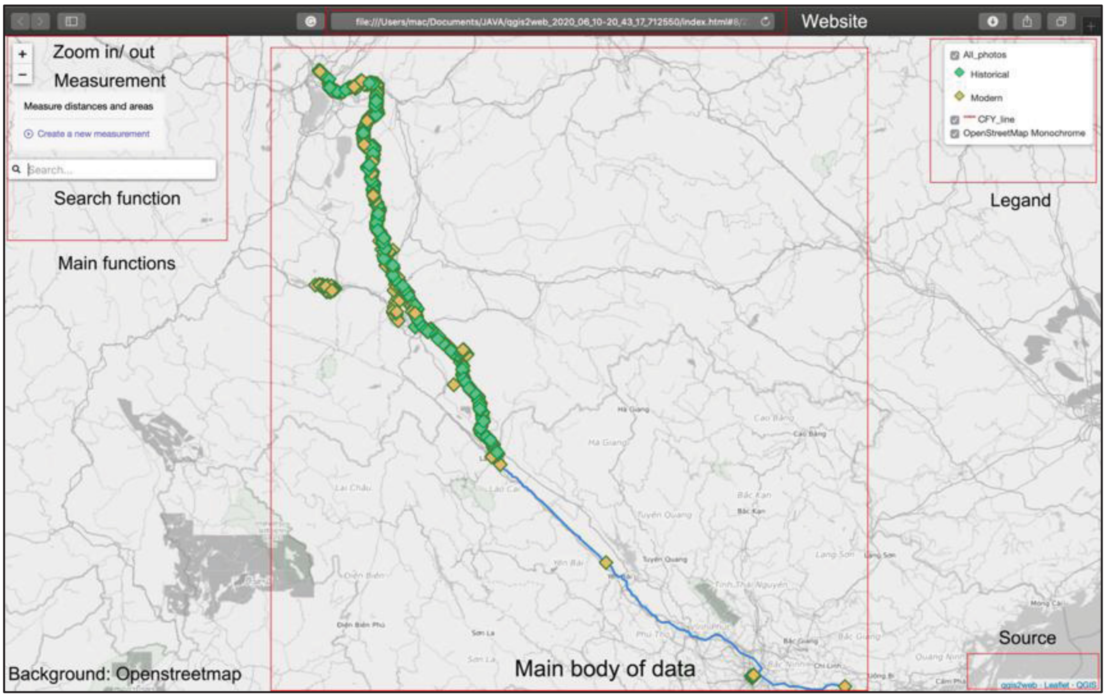

Figure 120, Components of the WebGIS

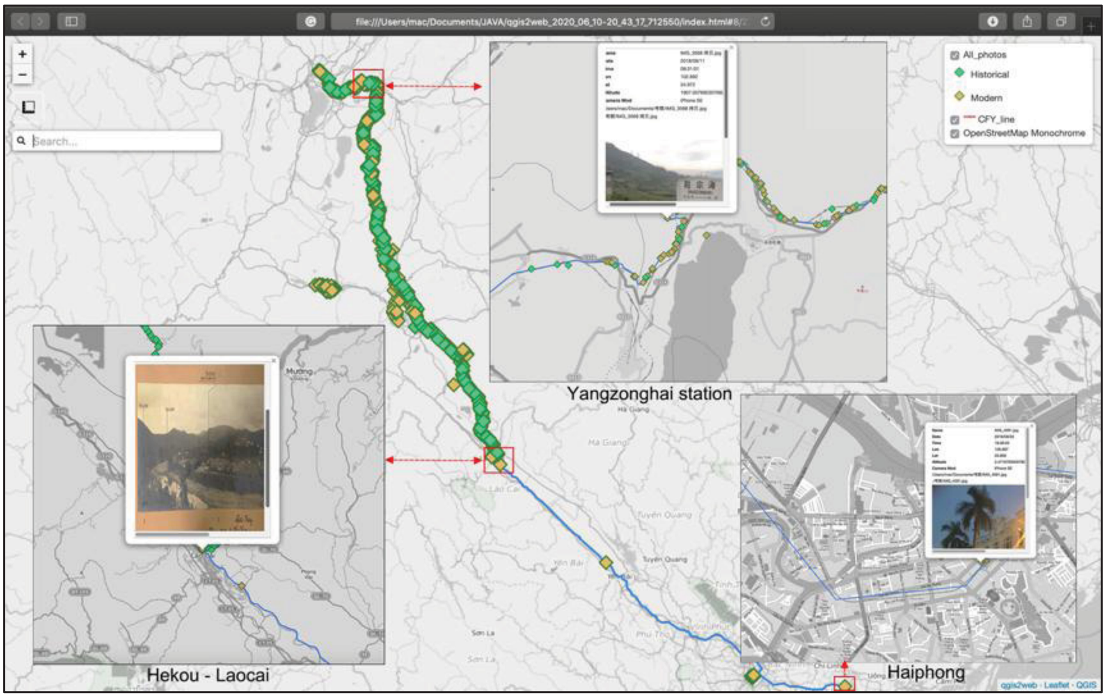

Figure 121, Detail of the photos on the page

4.4 Historical changes along the railway

Land use/land cover is an important factor for the regional development and the historical land change is also a hot issue in the HGIS studies. With the geo-historical data in the CFY heritage database, the analysis focusing on land use changing along the CFY will be helpful for providing insights in the cultural landscapes, the decision-making of future land management, the implementation of land conservation measures, as well as the redevelopment of CFY heritages.

After the digitalization of historical maps (in previous chapter), the historical land use is already obtained from the 1954 army maps, which contains four types of land use: forest, cropland, water body and urban area. Then, the current spatial data are also included in the database, which are the MODIS imageries from the United States Geological Survey. The MCD12Q1 Version 6 data product provides supervised classification data of global land cover types from 2001-2018 (Friedl & Sulla-Menashe, 2019). The land cover data of 2001 and 2018 at 500-meters spatial resolution are selected to do the comparison with the historical land use digitalized from historical maps.

Generally, the MCD12Q1 product covers 17 types of land use, but only four of them will be compared with the historical maps. Thus, the reclassification and vectorization of Modis land cover raster is required (table 23). Afterwards, the change of land cover can be calculated and compared quantitatively in GIS (figure 122). The vectors of land cover data are intersected with the administrative data of the study area. Then, the land cover is divided by the administrative boundaries in the study area, and a specific type of land use is calculated within every county. The result of land use change is output as a excel table show in table 24. The result is also visualized in GIS to show the land change rate between 1954-2001. It is seen that the counties with the highest change rate of water body are: Mile and Hekou; the forest coverage changed dramatically in Kunming, Chenggong and Pingbian; the urban area changed most in Chenggong, Yiliang and Maguan; cropland changed most in Yiliang, Hekou and Kaiyuan (figure 123).

Table 23, Original raster value and the rule of reclassification

Table 24, Land use change in CFY counties (Yunnan)

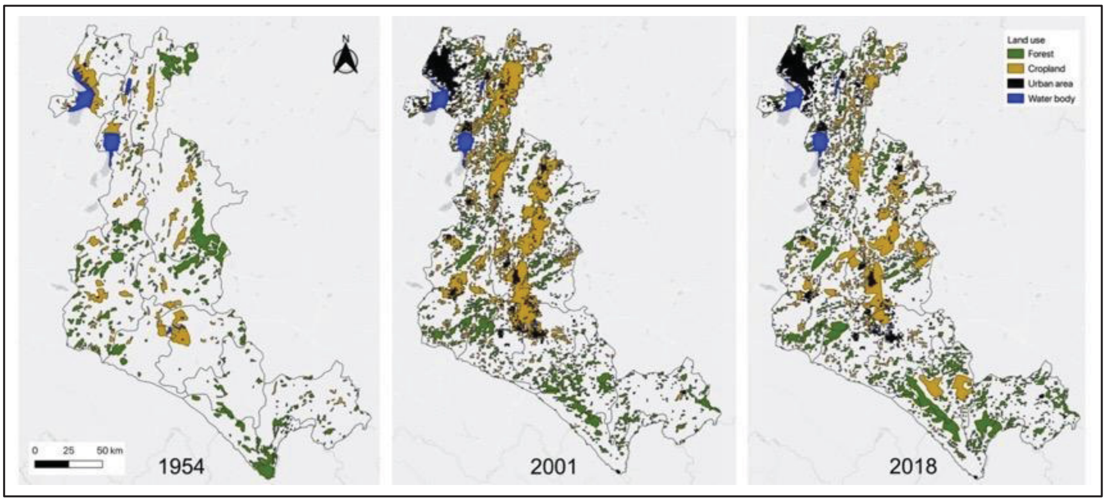

Figure 122, Result of land use changes from 1954-2018

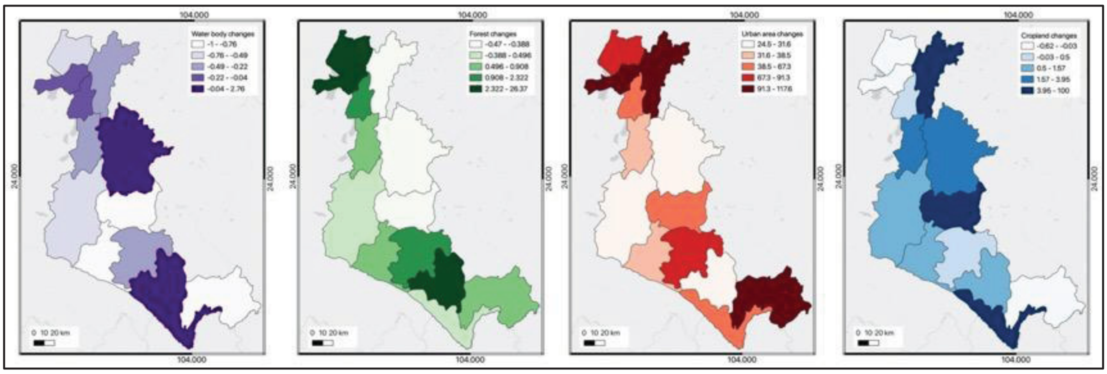

Figure 123, Visualization of the land use changes

As is seen, historical maps are the main material used for analyzing the historical land use. Along the CFY areas, after its construction, the urban areas were developed rapidly in every county passed by railway, especially near the two terminals in China (Kunming and Hekou). Then, water body is the element decreased in nearly every CFY county. But cropland and forest were changed variously in different areas. The land change data from the historical maps are firstly obtained, and it will be useful and meaningful for the future land management and land policy making. The land change data can also be associated with other socioeconomic data, such as population, economic growth and tourism data, to study further the relationship between railway, land, and other socioeconomic factors in the history. More historical maps and data need to be gained to cover the blank period of the development of CFY, especially before the railway construction. The historical data (maps and photos) for the Vietnam area are also lacked. Thus, in this analysis, it covers only the regions of CFY in Yunnan.

4.5 Data sharing

Nowadays, GIS has been transited from scientific and professional application to wider organizational, commercial and social uses. There are lots of GIS applications developed by various organizations and plenty of geospatial data generated with the development of information technology. A huge number of new spatial resources are being created every day. Sharing data among different stakeholders, organizations and communities is both necessary and meaningful, which means that all the users are freely to use and republish them without any restrictions. It is considered to be significant for government activities, which provides numerous benefits to the public administrations. Especially, the spatial data are of increasing importance within the public sectors such as topography, hydrography, cadaster, traffic management and other academic research (Groot & McLaughlin, 2000).

Based on the Web server, ArcGIS Online is a collaborative platform which enables GIS users throughout the world to create, edit, and share maps, services, and other GIS resources. ArcGIS Online contains a large variety of resources, including Web maps (consisting of a base map and several layers), services (map service, feature service, geoprocessing service, etc.), as well as document-based data (shapefiles, CSV, etc.). What's more important, ArcGIS Online also provides the function of data sharing and reuse mechanism, namely all the users can integrate the existing services into their own maps instead of having to upload all data. Thus, to archive the shareability of the CFY heritage data, in the end of this research, the datasets collected and used in are shared on ArcGIS online (figure 124), to support other related CFY studies.

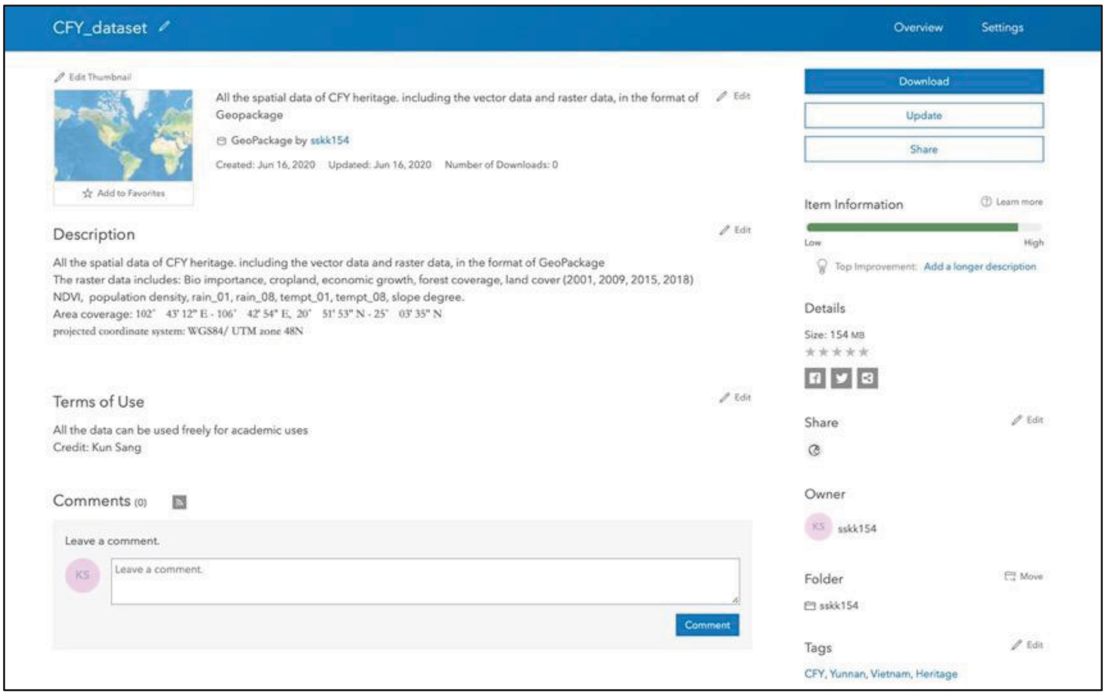

Figure 124, Sharing data on ArcGIS online

CHAPTER 5. DISCUSSIONS

In this research, HGIS is introduced as the main method to build the CFY heritage corridor. During this process, the steps of data acquisition, classification and data preprocessing and data management are done according to the main types of data (vector, thematic raster, remote sensing imagery and non-spatial data). The historical documents, including historical texts, photos and maps, associated with online open spatial data, big data from the internet and social media, and the data from fieldwork are the main sources for this research. After the classification of data based on the data format and topic, they are also processed to remove the errors and make them the appropriate formats for further spatial analysis. By georeferencing and digitalization, the historical information extracted from photos and maps are also imported into GIS. Then, all the raster data and vector data are organized and managed in GeoPackage.

For building the heritage corridor, the MCRM model is used to analyze the suitability of heritage tourism based on the land use type in the study area. The heritage corridor is composed of three levels, namely the core area, buffer zone and other backgrounds. And its spatial structure can be considered as the heritage cores connected by the CFY line. After the building the heritage corridor, the heritage classification is fulfilled, and the heritage evaluation is made from the aspects of landscape, ecology, technology, social culture and tourism. In this process, GIS integrates AHP and Delphi method as a spatial integrated assessment method.

Based on the CFY heritage corridor. Namely, the basic mapping functions can be done with comprehensive data in the heritage database. With the help of Web GIS, the heritage data can be visualized, especially for the heritage photos and fieldwork records, the WebGIS provides a platform to view the heritage sites and their details. Then, for supporting tourism activities, applications can be developed to find the related heritage information on the designed webpage. For other academic uses, all the data are shared through the ArcGIS online. However, there are also some shortcomings in this study, which are in needs of further research in the future.

5.1 Problems and difficulties in this study

5.1.1 Data collection process

There are also other research methods tried by the author to collect comprehensive data along the CFY. A questionnaire was designed to measure the tourists' satisfaction from the aspects of natural view, cultural character, traffic condition, heritage management, safety and regional sustainability. The objective was to collect answers in the main tourism destinations along CFY, to figure out the tourists' attitude towards the CFY heritage tourism. However, the passenger flow was strongly different among different sites, some of them are popular for both national and international visitors, other sites are hard to be accessed or just known by the locals and railfans. At last, the questionnaires were just collected in a few main cities (Kunming, Kaiyuan, Mengzi, and Hanoi), which could not cover the whole study area. Therefore, the quantitative method for tourists' satisfaction research still needs more time to fulfill, which will not be included in this thesis.

Then, some historical data are also lacked within the study area of Vietnam compared with the abundant historical records in Yunnan. For example, there are few historical maps and photos collected in Vietnam. The reason why the railway company took only photo of the Yunnan section still needs to be further discussed. Because of the language problem, the author has visited only a few museums in Vietnam (both Hanoi and Ho Chi Minh city). The touristic train in Vietnam only provides services during the night, which makes the data collection really difficult. Thus, the future research needs more cooperation with local scholars to systemize the Vietnamese documents and to make them available for more international scholars and various studies. And more fieldworks during the day are necessary to survey the current landscape quality along the trip in the Vietnamese section of CFY.

5.1.2 Update of data in geodatabase

A spatial database is a series of datasets describing the real-world objects (georeferenced objects) related to a specific spatial location. It is a collection of spatial characteristics, such as position, shape, range, distribution, etc. and the spatial processes, recording the geometric and attribute characteristics and positional relationships of spatial objects. The special feature of a geodatabase is its high efficiency in storing spatial data, establishing connections and the spatial analysis and visualization. Continuously updating the spatial database to keep the information in the database consistent with reality has become an important long-term mission. The format of GeoPackage is utilized in this research for all the related CFY heritage data. However, the update of data in the heritage database is less concerned in this research.

Moreover, the CFY heritage relates to both spatial data and non-spatial images. The digitalized geo-historical data are limited to a specific time span. But other heritage data need to be updated as its development. For example, the data in the list of railway heritage is dynamic. There are more physical sites that can be included, or the sites lost the heritage value will also be removed from the list. The environmental data around the heritage sites are also needed to be updated to reflect its changes, such as the near real-time satellite imagery. There are some studies already discussed the technique of updating data in the geodatabase (Bai & Li, 2011; Zhao, et al., 2018). Thus, the technique and methods of data updating in the CFY heritage system need to be studied and implemented further in the future research.

5.1.3 The accuracy of photos localization

To show the current situation of heritage sites and their related landscape, the author used a smartphone equipped with GPS to record the fieldwork along the CFY line, then attached and displayed them with the help of WebGIS. However, due to the limited accuracy of the GPS device and the difficulties for accessing all the sites of CFY, the railway heritage and landscape of CFY are partially recorded. There are other observers or tourists have already visited the sites and uploaded their photographic works on social media. The footprint of their published works is collected and analyzed by the author from Weibo and Flicker, to reflect the popularity of CFY sites among visitors. But these photos cannot be imported in the heritage database due to the copyright problem. Importing more site photos into the database to cover the whole study area for serving the heritage tourism is a problem waiting for solutions.

Then, the historical photos from archives are also protected for their copyrights. The author got the authorization to used and published them in this research. However, there are lots of historical photos without any title or records to be identified, which increased the difficulty for the localization of their location of shooting. Some of the historical photos are geotagged according to the distance information, but other locations are just estimated in GIS. Thus, the geotagging of these historical photos is with lower accuracy. The identification and localization of CFY historical photos can be another independent project, and the interpretation of the historical photos also needs more supports and helps from the local historians and other CFY experts.

5.2 Suggestions for Chinese railway heritage

Railway heritage study is still not an eye-catching topic in China, but there is an increasing attention to the protection and reuse of industrial heritage and railway heritage in recent years. More research and practical studies started to focus on railway heritage and heritage tourism. In the Chinses cultural heritage list, the single railway stations and railway bridges are the main components of the Chinese railway heritage. At the same time, there are seven railway heritages inscribed in the national industrial heritage. China owns rich railway heritages with various types, which embodies the memory of industrial age, recording the development of China's modern railway history. Protecting and updating these railway heritages and developing them in heritage tourism can not only enhance the competitiveness of railway in the tourism market, but also satisfy the nostalgia of steam ages, the willingness of getting close to natural environment, as well as enhancing the cultural identity for locals. Based on the discussion of building CFY heritage corridor and its evaluation and application, the following suggestions are proposed for other railway heritage redevelopment from a national perspective.

5.2.1 Geo-historical approach for heritage study

Since the introduction of GIS into history and historic geography, it has solved many technical and spatial problems difficult in former studies. A large number of historical data in different scales and types are being spatialized and digitized, such as ancient maps, old remote sensing images, historical photos, place name, archaeological sites, local history, genealogy, travel literature, poems, etc., in order to construct the comprehensive HGIS system. The integration of geo-historical approach and history-related issues within the digital humanities in the information era will present more possibilities and new trends in the future, and the deepening of analyzing historical documents in the digital environment will surely promote the expansion of the time range in geographic space in GIS research. However, because of the different characteristics from the modern geographic information, historical spatial data has some different expression methods in terms of scale, precision and projection, which brings difficulties in the georeferencing and digitization of historical data, such as the projection error and edge connection problem. Further research is still in need to deal with these problems (Zhao & Chao, 2020).

Historical documents, especially the primary sources, are of great value for heritage and archaeological studies. For CFY, the related historical documents were studied to analyze its influences and roles in the history. But the historical images of railway heritage are always ignored or just as exhibitions in the museum. For the railway heritage studies in China, the geo-historical approach brings new meanings and perspectives. The historical images of railway heritage record the personal activities of photographers, the character of an age and the ancient environment and landscape. They can be regarded as a part of the movable heritage of railway, serving for the heritage restoration. At the same time, the historical data can be display, managed and analyzed in the spatial environment, especially the data hidden behind the historical photos and maps. For the railway heritage, their historical spatial data can be utilized to complete the heritage visualization, classification, evaluation and other spatial analysis combined with the current heritage data.

5.2.2 National railway heritage database

Historical geodatabase can provide a unified spatiotemporal standard for all historical data and products in a multidimensional platform for various types of data in graphics, images, text, video, and audio formats. It can realize a seamless connection of multiple data, ensuring the consistency, compatibility and convertibility of historical geospatial data. The construction of historical geodatabase aims to provide the scientific researchers with easily accessible and universal historical geographic information services, help the public to get a better and easier understanding of history and culture.

Currently, the correlation among Chinese railway heritages from a national scale is weak. There is no connection built between the forest railway, narrow-gauge railway, mountain railway, urban tramway and other heritage types. Researchers are doing separate research focusing on different cases in different provinces. But from a national level, the railway heritage management network and national database system have not been formed yet to coordinate all these scattered heritages, especially, for the large-scale railway heritages, which are relating to a large spatial extent; dynamic environment; complex heritage elements and a massive amount of data. The CFY heritage database can be a good reference. Not only the heritage list is digitalized into the spatial database, other useful information of the whole region can be also included to form this comprehensive heritage system. Then, it can realize the unified storage and management of heritage data and regional data, improve the performance of data storage and sharing capacity, implement the index mechanism, and provide a fast and reliable environment for data query and processing in this heritage system.

5.2.3 Landscape and railway heritage

Landscape and railway interact with each other. The construction of railway influenced the landscape ecology, but the railway elements also become part of the landscape aesthetics. The changes brought to society by the mobility of railway is called the discovery of landscape along the rail. The feature of heritage corridor in this research lies in the combination of railway heritage elements and the regional ecological and landscape elements for its tourism development, seeing the cultural and natural elements closely linked with each other. In the past, the analysis of industrial heritage value mainly focused on its technological value. But the heritages are always located in an environment and being a part of its surrounding. Railway landscape can be regarded as a part of railway heritage, and the landscape quality influences the attractiveness of the heritage sites and their value. In particular, the study on the evaluation of railway landscape quality is still lacked in China.

In the process of developing railway heritage, we should pay attention to not only the physical remains as isolated railway elements, but the value of landscape should also be taken into consideration. Protecting the overall landscape along railway should be one of the scopes of railway heritage conservation. All kinds of natural and human landscapes along the route can be included in the railway heritage system, and the landscape quality needs to be one of the factors for the evaluation of the value of the railway heritage. Besides, there are also more topics waiting for further research and practices, such as the combination of transportation management and service with the heritage protection, dynamic evaluation of visual quality along railway, the construction of 3D visualization of railway landscape for tourists, the reconstruction of historical railway landscape and so on.

Appendix 1, Questionnaire for experts

The author is trying to build a system for assessing the heritage value of the linear area where a heritage railway (Yunnan-Vietnam Railway) is passing through. According to former studies, the value of this heritage railway can be reflected from the following five aspects: landscape, ecology, technology, social-culture and tourism. Further indicators are selected and explained how they influence the value of this heritage railway.

You are invited as the expert to complete this assessment system. Based on your research background and knowledge, please compare each pair of two indicators of heritage value. If the value of the first indicator is given as 1, then what value will you give to the second indicator according to the criteria table (choose one of the 9 numbers to fill out the tables below):

-9	**-7**	**-5**	**-3**	**1**	**3**	**5**	**7**	**9**
Extreme less important	Very less	Strong less	Moderate less	Same Important	Moderate more	Strong more	Very more	Extreme more important

1) Landscape value factors: Scenic spots, visibility, river system

Scenic spots: all the natural and cultural scenic spots (such as national parks, historical sites…) in the study area, the place closer with those scenic spots has a higher landscape value.

Visibility: taking the railway as a traveling method, the place can be perceived by the visitors has a higher landscape value.

River: in the study area, where there contains a higher river density, it has a higher landscape value.

Compare the importance of these three factors:

Scenic spots: 1								
-9	-7	-5	-3	1	3	5	7	9
Visibility: (fill out here the value that you will give to this indicator from -9 to 9)								

Scenic spots: 1								
-9	-7	-5	-3	1	3	5	7	9
River:								

River: 1								
-9	-7	-5	-3	1	3	5	7	9
Visibility:								

2) Ecological value factors: Vegetation coverage, Naturalness, Biodiversity

Vegetation coverage: the vegetation index is used to indicate the coverage of vegetation in this area, a higher coverage by live green vegetation indicates a higher ecological value.

Naturalness: classify the type of vegetation, the natural forests have a higher ecological value, while the artificial vegetation has a lower value.

Biodiversity: the place with a higher biodiversity importance (provided by World Database of Key Biodiversity Areas) means a higher ecological value it owns.

Vegetation: 1								
-9	-7	-5	-3	1	3	5	7	9
Naturalness:								

Vegetation: 1								
-9	-7	-5	-3	1	3	5	7	9
Biodiversity:								

Naturalness: 1								
-9	-7	-5	-3	1	3	5	7	9
Biodiversity:								

3) Technical Value factors: Historical richness, Topographic difficulty, Climate suitability

Historical richness: the conservation of historical railway remains (both the physical buildings, structures and the related historical documents), the more remains a place owns, means a higher technical value.

Topographic difficulty: in the process of railway construction, the first challenge was the mountains and slopes. Thus, a more complicated topography means a higher technical value.

Climate suitability: the climate and sanitary condition were also the difficulties in the history. Thus, the bad climatic conditions in the area mean a higher technical value.

Historic richness: 1								
-9	-7	-5	-3	1	3	5	7	9
Topographic difficulty:								

Historic richness: 1								
-9	-7	-5	-3	1	3	5	7	9
Climate suitability:								

Topographic difficulty: 1								
-9	-7	-5	-3	1	3	5	7	9
Climate suitability:								

4) Social-cultural value factors: Population density, Cultural diversity

Population density: the place owns a higher population density means the railway is serving for more people, indicating a higher social-cultural value.

Cultural diversity: the place passing through the Minority Areas, means the diversity of cultural it owns, indicating a higher social-cultural value.

Population density: 1								
-9	-7	-5	-3	1	3	5	7	9
Cultural diversity:7								

Population density: 1								
-9	-7	-5	-3	1	3	5	7	9
Economic growth:								

Economic growth: 1								
-9	-7	-5	-3	1	3	5	7	9
Cultural diversity:								

5) Tourism value factors: Touristic services, Accessibility, Popularity

Touristic services: the place has more touristic services (restaurants, hotels…) means a higher tourism value.

Accessibility: the place can be easily arrived by other transportations means a higher tourism value.

Popularity: the place where it is visited by more visitors is more popular, means a higher tourism value.

Comparison:

Touristic services:1								
-9	-7	-5	-3	1	3	5	7	9
Accessibility:								

Touristic services:1								
-9	-7	-5	-3	1	3	5	7	9
Popularity:								

Accessibility:1								
-9	-7	-5	-3	1	3	5	7	9
Popularity:								

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