Viabundus

Map of premodern European transport and mobility

Documentation, Version 1.1

by Bart Holterman, Maartje A.B., Maria Carina Dengg
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Introduction

Viabundus is a freely accessible online interactive map of long-distance routes in pre-modern northern Europe. Next to providing a map of roads and waterways, the map is connected to a database with information about places along these routes. Moreover, it incorporates a route planner with rough estimations of travel times. Viabundus is primarily intended as a tool for researchers of pre-modern history that helps to understand and incorporate a spatial factor in all kinds of historical research. As the project originated from an economic historical background, the map contains much information about financial aspects of travelling and regional economic structures, such as toll stations, staple markets and fairs. However, the map is also of interest for various other topics, such as pilgrimages, archaeology, the spread of art and ideas, etc. The map is, of course, of interest to anyone interested in pre-modern travelling and the historical roots of the modern European landscape.

The period 1350-1650 has been chosen as a time frame, for the following reasons. First, the sources concerning travel routes are extremely scarce before 1350, which makes it hard to create reliable reconstructions of the European road network. Second, at the end of the 17th century the structure of the road network, which had developed naturally and largely remained constant over centuries, started to change rapidly and profoundly. First by the construction of canals, the canalisation of existing waterways and the construction of straight long-distance roads (*Chaussee* or *Kunststraße*), to be accelerated in the 19th century with the industrialisation, urban sprawl and the construction of railroads.

Currently, the region that is covered is limited to the regions on the European continent that border the southern shores of the North and Baltic Seas, i.e. Flanders, the Netherlands, northern Germany, Denmark, Poland, the Baltic states and the northwestern corner of European Russia. This is related to the initial idea behind the Viabundus project, which was to digitise the Atlas *Hansische Handelsstraßen* by Friedrich Bruns and Hugo Weczerka from 1962.[1] In their work, they focused on

1 Friedrich Bruns and Hugo Weczerka, *Hansische Handelsstraßen*, Quellen und Darstellungen zur hansischen Geschichte N.F. 13 (Köln; Graz, 1962-1968), 3 vols.: *Bd. 1: Atlas* (1962); *Bd. 2: Textband* (1967); *Bd. 3: Register* (1968).

the overland trade routes within the area of economic influence of the German Hansa, a community of towns and merchants with shared commercial interests that connected Novgorod in the east to Bruges and London in the west and extended south to the larger urban centres in central Europe such as Nuremberg and Prague. As this work provided a well-researched, convenient starting point for a digitisation of the northern European pre-modern road network, it also defined the geographic scope of the map. Of course, this geographic scope can be expanded in the future.

The atlas of Bruns and Weczerka has a number of limitations. First, as the perspective of the work was strictly Hanseatic, only those routes were mapped that provided a connection between Hanseatic towns or major trade routes to the most significant trading centres of the Hanse abroad. This means that for areas in the Hanseatic periphery, such as Denmark or the Netherlands, significant local roads and places have not been displayed in the atlas when they did not play a role of significance for the Hanse. Second, Bruns and Weczerka focused on land roads and included waterways only to a very limited degree, although these were often viable alternatives to the land routes. Third, the maps in the atlas provide few details and are drawn on a large scale. Finally, information about important points along the route (e.g. tolls, bridges, watchtowers) is limited and spread out in a lengthy text volume and therefore difficult to link directly to the maps in the atlas. Many of these limitations were caused by the limitations of a printed map; a digital map allows the incorporation of both large-scale and small-scale elements as well as the direct linking of elements on the map with additional information.

After a digitisation of the *Hansische Handelsstraßen* atlas, the Viabundus map therefore expands the scope of the map, by 1) supplying a more precise reconstruction of pre-modern long-distance roads, which allows to view the routes on town level[2]; 2) including navigable waterways[3]; 3) incorporating all towns within the covered area; 4) supplying a modern background map as well as a reconstruction of the landscape around 1500; 5) linking the elements on the map to a database with information about the settlements along the routes as well as other information related to the choice of routes or travel costs, such as staple markets, tolls, bridges, ferries and fairs.

Challenges

Of course, these objectives are met with numerous challenges, both on a theoretical and practical level. On a theoretical level, one of the most challenging problems is the fragmented nature of historical information. As the project focuses on a time in which the use of writing is rapidly developing in all levels of society, the researcher is faced with an uneven spread of evidence, which means that much more information is available for the situation in 1650 than in 1350. Moreover, information has been lost over time and some places and topics have received more historiographical attention than others.

Another challenge is the multifaceted nature of many of the included elements. For example, there existed a large number of various fees that a traveller had to pay on the road, such as transit tolls, road tolls, bridge tolls and fees for safe conduct, which we can summarise as tolls (see Toll). It happened regularly that certain groups (e.g. citizens of a certain town) were exempted from toll payments, or that toll only had to be paid for certain commodities. Moreover, in some instances the right to levy a toll was granted but the toll was not actually levied, or a toll was levied illegally.

A third complication is that circumstances changed over time. Even though the road system in general remained quite constant throughout the three centuries under discussion, single elements

2 Not all roads inside towns have been included, only the thoroughfares.

3 Note that only inland navigable waterways and direct coastal connections between islands have been covered. Sea travel has so far been left out because it depends on conditions very different from those of travel on inland waterways and land roads. Sea routes may be included in a future version of Viabundus, however.

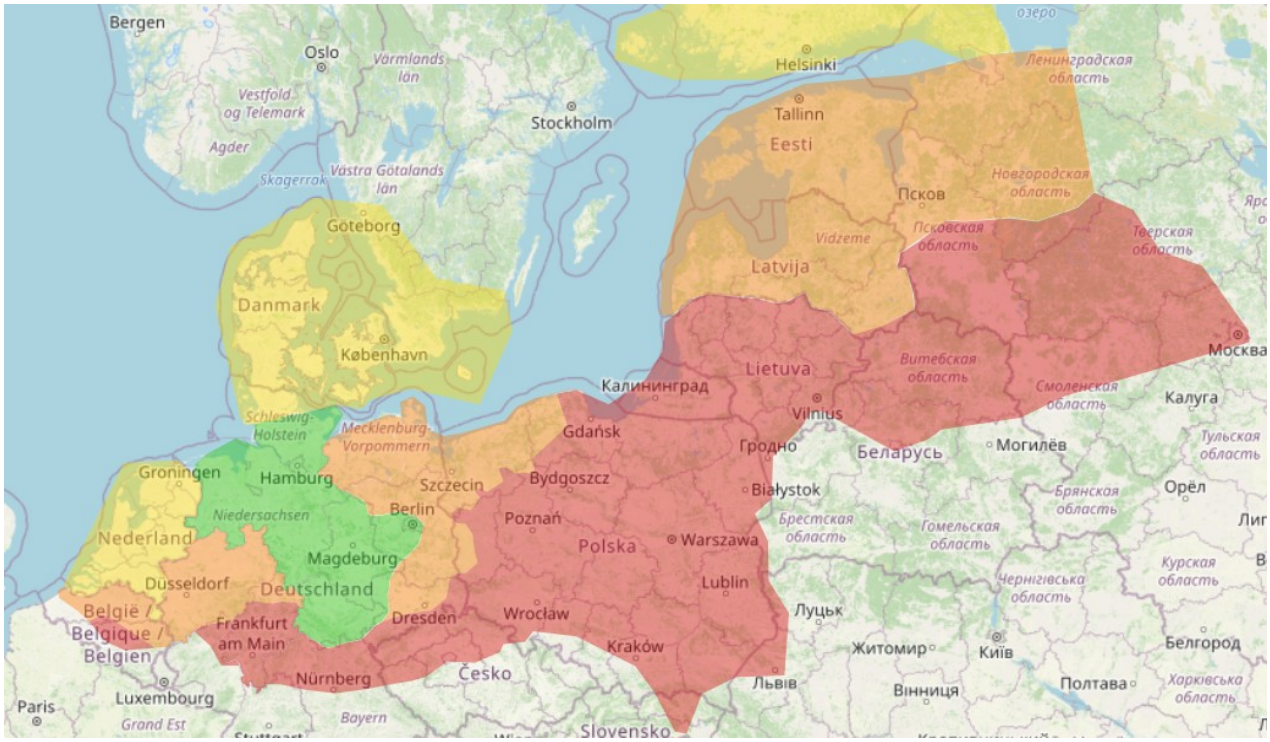
appeared and disappeared or changed their character over the years. This also happened on a small timescale: whether a route could actually be travelled depended on the weather and the season. Shipping could be hindered by low water levels in summer or ice in winter. As most roads were unpaved, they could become impossible to use in wet weather, especially in low-lying areas. Moreover, actual travel was often defined by temporal events such as religious feasts or fairs, or hindered by political circumstances such as feuds or wars.

It is hardly possible to include all of the factors sketched above in a digital system with all of their nuances and uncertainties. Unavoidably, the quality and quantity of the information for some elements will be better than for others. For this reason, all elements are supplied with a text field that makes it possible to describe the characteristics of the element in more detail. Moreover, references have been added where applicable, making it possible for the user to find more information in the literature or on other websites. Finally, all elements on the map have been supplied with the possibility to frame their appearance in time by supplying a start and/or end year.

Project structure: a work in progress

From a practical perspective, the research for a detailed reconstruction of the road network according to the standards described above is a very time- and labour-consuming process. For this reason, the refining of the map after the initial digitisation of the *Hansische Handelsstraßen* atlas has taken place for single regions in single subprojects taking place at various partner institutions. The team at the Institut für historische Landesforschung (IHLF) at the University of Göttingen, in cooperation with the Forschungsstelle für die Geschichte der Hanse und des Ostseeraums (FGHO) in Lübeck, has created the digital system as well as the initial digitisation of the atlas of Bruns and Weczerka. Moreover, the IHLF has provided the research of the region covering the modern German state of Lower Saxony, parts of Estonia and Latvia and the historical duchy of Pomerania; the FGHO has supplied information for the region Holstein and Mecklenburg. At the Otto-von-Guericke-Universität in Magdeburg, a subproject has covered the region central Germany, including the states of Saxony-Anhalt, Thuringia and parts of Brandenburg and Saxony. At Moesgaard Museum/University of Aarhus, the historical kingdom of Denmark is being researched, including the duchy of Schleswig (now in Germany) and Scania (now in Sweden). A subproject at the Radboud University in Nijmegen is working on the road network in the current-day Netherlands. Finally, a grant of the Kone foundation recently enabled the launch of a Finnish subproject at the University of Tampere. Further regional projects are being planned.

It should be noted that Viabundus is a work in progress. For the user, this means that the quality and depth of the information supplied on the map differs largely between different regions: some regions are well-researched (Lower Saxony and Central Germany), others are still being worked on (Netherlands, Denmark, Westphalia, Holstein, Mecklenburg, Estonia and Latvia), whereas still other regions remain limited to the basic digitisation of the routes in the *Hansische Handelsstraßen* atlas. In order to make this clear to the user, a number of features have been included, such as the "ready" checkmark for the places (see The nodes data model) and the "certainty" attribute for the routes, which has been set to uncertain for all roughly digitised roads (see Edges data model) and are therefore displayed as a dashed line.



The current state of research in the regions covered by Viabundus. Green: ready; yellow: extended research in progress; orange: road network reconstructed with historical maps, no further research planned yet; red: rough digitization of the road network with modern maps, no further research planned. Note that the Finnish Viabundus sub-project is in its initial phase: no data is included in the database yet.

Versions

Viabundus is not only an online map, but the data collected to assemble the map are available as free downloads as well. This allows users to work with the data in an external database or GIS application. Because of Viabundus‘ nature as a work in progress, the downloads have been assigned version numbers. For each version, a detailed description of state of the work at the moment of publication is available; older versions can be downloaded as well. The files will also be stored in digital repositories.

What’s new in Version 1.1?

Version 1.1, released on 5 December 2021, contains the following changes since the previous version 1.0:

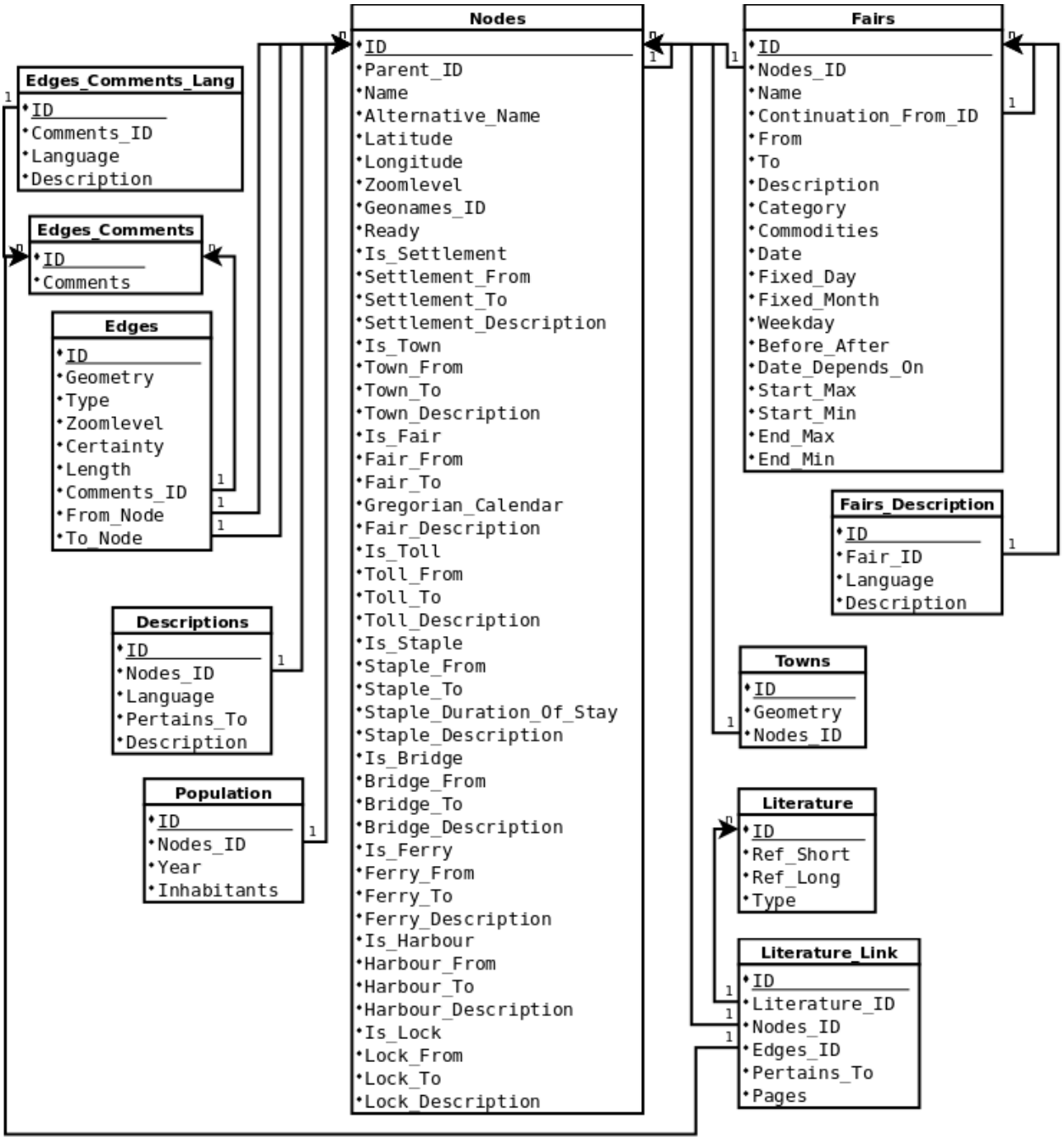
- Inclusion of the street network of Denmark and Schleswig.
- The roads of the German states of Brandenburg, a large part of Saxony and the nowadays Polish region of Farther Pomerania (*Hinterpommern*; roughly identical with the modern West Pomeranian Voivodeship) have been corrected for historical accuracy.
- Information for nodes in Holstein has been completed.
- All towns before 1650 and the routes connecting them have been added for the former duchy of Mecklenburg.
- Ongoing improvement of the Dutch street network and nodes.

- The Oder river with tributaries was added as navigable waterway between Krosno Odrzańskie and the Baltic Sea.
- More reliable performance of the Route calculator due to inclusion of the fields *From_Node* and *To_Node* in the Edges data model, pointing to the start and end node of each segment in the Nodes table.

The Viabundus data model

The Viabundus map and database is designed according to a network model: Places are represented with points on the map (called *nodes*), which are connected to each other by lines (called *edges*) which represent the roads and waterways. Each edge connects two nodes with each other, whereas nodes can be connected to theoretically an unlimited number of edges. However, since a map represents a spatial network that is limited by geographic structures, in practice each node will be connected to a few edges only. Both the nodes and edges are supplied with additional data that informs about the structure of the network and the relation of the various elements to each other.

The structure of the database is displayed in the schema below. The fields included in the main tables *Nodes*, *Edges* as well as *Fairs* will be explained in the corresponding sections below. The *Descriptions* table contains descriptions of the elements in the *Nodes* table in languages other than English, as does *Fairs_Description* for the *Fairs* table. *Edges_Comments* contains comments for single route segments in the *Edges* table in English, *Edges_Comments_Lang* contains the same in other languages. The *Population* table has the Population figures for single nodes and *Towns* contains the geometry of the Town outlines (16th century); both are described in further detail below. Finally, the *Literature* table contains literature references, which are connected to the *Nodes* and *Edges* via the *Literature_Link* table.



The Viabundus database schema.

Nodes

The nodes represent the places that are visited by a traveller. More specifically, they are defined as any place that might require an action of the traveller: change the followed road, pay a fee, change means of transport, cross a river, reach a destination, etc. Each node can be supplied with attributes that give information about the character of the node. There are nine different attributes available: settlement, town, toll, staple, fair, ferry, bridge, harbour and lock (for ships). These will be explained in further detail below. A node without any attribute can be considered a simple junction.

Because Viabundus aims to be as detailed as possible in the reconstruction of the road network, a cluster of nodes exists in more complex situations where many roads meet. In many cases, these are located within towns, so that certain attributes, such as Town, Toll and Staple, can be relevant to all of them. For this reason, some nodes have been made subordinate to others. The subordinate nodes are called child nodes, and the node to which they are subordinate accordingly the parent node. The attributes Settlement, Town, Staple and Fair can only be appended to parent nodes, and they are consequently valid for all of its child nodes as well.

An example is the town Hann. Münden, an important staple for river transport located on the confluence of the Weser, Werra and Fulda rivers, as well as on the important land road between Göttingen and Kassel. Due to natural and man-made barriers, it was not possible for ships to sail directly from one river to another, resulting in separate loading quays for traffic on each of the three rivers. The situation is therefore mapped using six nodes (see image): node 1, the central node, is the parent with the attributes Settlement, Town and Staple. The nodes 2-4 (the three harbours) and 5 (the bridge across the Werra) are children of 1, and consequently the Settlement, Town and Staple attributes are valid for them as well. Node 6, a junction of two land routes to the north, is an independent node as travellers on those routes did not necessarily enter town.

The nodes data model

Each node is represented by an entry in the Viabundus nodes database and has the following fields:

Name	**Type**	**Description**
ID	Integer	A unique identifier
Name	String	The name of the node according to the modern official name in the national language. This name is shown on the map. For names in non-Latin scripts, the standard English transliteration is entered.

		Optionally, an addition can be placed between brackets to discern the place from another one in the database with the same name, e.g. Frankfurt (Oder).
Alternative_Names	String	All other names for the node, either modern spelling variants, official names in other languages, official names in non-Latin scripts and historical names and spellings. These are to be separated with a semicolon.
Latitude *Longitude*	Floating point number	The Latitude and Longitude fields contain the coordinates in the WGS 84/EPSG:4326 coordinate reference system.
Geonames ID	Integer	The ID number of the place in the Geonames database (geonames.org).
Parent ID	Integer	Links to the ID number of another node in the database in the case that the node is a child node.
Ready	String (1)	A “y” in this field indicates that the information for this node can be considered correct and complete. This is indicated with a green check mark on the Viabundus website. Nodes that are not indicated as ready can be considered a work in progress. Of course it is possible that information can be changed for or added to nodes that are marked as ready. It is merely an indicator of the state of research for the selected node.

Apart from these general fields, each attribute contains the following information. For the attributes staple and fair, additional fields are added. These are described at the respective attributes below.

Name	**Type**	**Description**
Is_Attribute	String (1)	If a node is indicated with the selected attribute, this field receives a “y”.
From	Integer (4)	A year in which the attribute first appears. Usually, this is the year in which the attribute is first mentioned in written sources. However, in many instances there is good reason to choose another date. This will be specified in the *Description* field. For inexact dates (e.g. “first mentioned in the 12th century”, “constructed between 1365 and 1388”), the first possible year is included and the elaboration included in the Description. The *From* field can be left blank, in which case it is assumed that the attribute existed from at least 1350 onwards.
To	Integer (4)	The first year in which the attribute did not exist anymore. Can be left blank, in which case it is assumed that the attribute existed at least until 1650.
Description	String	A short characterisation of the attribute. The type of information included in the *Description* field depends on the attribute, see below.

Languages

The language of all *Description* fields in the Viabundus database is English. However, translations in other languages can be added. These are stored in a separate table in which each entry links to an ID number in the nodes table, with a reference to which attribute the description relates. The language is stored in a separate field with a language code. Currently, next to English there are three possible languages supported by the database: Danish (DK), Dutch (NL) and German (DE). More languages can be added in the future.

Population figures

For many of the larger settlements, estimates of historical population figures have been provided from the database "The Population of European Cities from 700 to 2000", compiled by Maarten Bosker and Eltjo Buringh.[4] The database is an extension and refinement of Bairoch et al.'s *La population des villes européennes de 800 à 1850*[5] and presents approximate estimates of population figures (in steps of 1000 inhabitants) of European towns for each century between 700 and 1500, and after 1500 for every 50 years. Because of the scope of Viabundus, only population figures for settlements in the database were included for the years 1300-1650. It is important to keep in mind that these figures represent rough estimations that were included because they might provide an indication for the importance of a settlement within the network. The data were not altered or corrected in any way by the Viabundus project researchers and do not incorporate possible more exact estimates from regional literature.

Attributes

Settlement

A settlement has been defined as any place that is inhabited by humans. In most cases, a settlement will be a village or town, but other types of human habitation are indicated as settlements as well: single farms, monasteries, watchtowers, castles, mills, inns and hermitages. In many cases multiple types of habitation will be combined in one settlement. In the description field of the settlement attribute, the main characteristics of the settlement will be described. The *From*-field will usually contain the year of first mention of a settlement, according to the general rules described above. Of course, most settlements were much older than their first mention. Archaeological evidence has incidentally been included, but could not be entered systematically for practical reasons.

Information for many small settlements is very scarce and research on it is very time-consuming. For this reason, it has been tried to include at least a year of first mention for each included settlement in the regions covered by the sub-projects (see Project structure: a work in progress). This is greatly helped by etymological works on place names and historical overviews of places, such as the work of Dutch place names by Van Berkel and Samplonius,[6] Laur's *Historisches*

4 https://www.doi.org/10.17026/dans-xzy-u62q For more information see Eltjo Buringh, "The Population of European Cities from 700 to 2000" , *Research Data Journal for the Humanities and Social Sciences* 6:1 (3-9-2020), 1-18. https://doi.org/10.1163/24523666-06010003

5 Paul Bairoch, Jean Batou and Pierre Chèvre, *La population des villes européennes de 800 à 1850* (Geneve, 1988).

6 G. van Berkel and K. Samplonius, *Nederlandse plaatsnamen verklaard* (2018). Online at Sijs, Nicoline van der (ed.), *Etymologiebank*, (http://etymologiebank.nl).

Ortsnamenlexikon for Schleswig-Holstein[7] or the *Baltisches Ortslexikon*[8] for settlements in modern-day Estonia and Latvia. These works often also provide the contents for the *Alternative Names* field. For some regions, such works are not available, and not all settlements have been described.

The selection criteria for the inclusion of settlements are threefold: first, all settlements included in the maps from the *Hansische Handelsstraßen* atlas have been included in the database. In the case that the settlements mentioned by Bruns and Weczerka can be proven to have existed only outside of the covered time frame 1350-1650, they have been removed or hidden on the map. Second, for streets and regions not included in the atlas, settlements have been included when they were important economic and cultural centres in their own right, i.e. important destinations and central nodes in the road network. In many cases, these settlements were towns, hence all towns in the researched regions have been included (see Town). Third, settlements have been included when they are mentioned in itineraries or travel descriptions as waypoints, or when they played an important role in the road network, e.g. as toll stations (see Toll). Two types of settlements are especially of relevance here: inns and watchtowers.

Inns and other places to eat, drink and spend the night could make a difference in the distance people could travel in a day, and thus in the travelling speed. Inns located outside settlements have therefore been incorporated in the Viabundus map as much as possible. Within settlements, inns may be named in the description. We have chosen not to be elaborate on inns and their location within town walls, since one may assume each urban place to have had at least one place to spend the night. The identification of inns in and outside town walls and settlements should be considered far from complete. Partly, this is caused by the fact that they are hardly mentioned in historical sources. Additional research on inns and the systematic inclusion of other places to spend the night on the map, could improve our understanding of the functioning of the late medieval and early modern road system for long-distance transport and mobility.

Watchtowers outside of the town walls were often part of the urban defensive system in a wide area around the town (NL: Landweer / DE: Landwehr). The towers were positioned at elevations or where the main streets would cross the border of the urban area. Often the street could be closed with a barrier to control the traffic. In many instances, towns levied a toll at the watchtower. Moreover, the watchtowers were often accompanied by an inn, where travellers could spend the night when they arrived after the closing of the town gates. As for inns, the watchtowers of the urban defensive enclosure have not been included systematically, but only when they formed important waypoints and were located directly on the road. More elaborate studies of the urban defensive system are referred to in the references.

Town

A special type of settlement are towns, which often function as central places and focal points within the social, economic and cultural network. In the medieval definition, towns were places with special privileges granted by the local lord. These privileges could include the right to hold markets (both weekly and annual markets: see Fair), minting privileges, the right to fortify a settlement with stone walls or earth ramparts, the exemption from tolls and other payments, and a certain degree of legal autonomy from the lord. The latter aspect is often represented by the existence of a burgomaster, town council and a community of citizens, a town hall and a town seal as symbol of the status of legal body. In the case of free imperial cities (‘freie Reichsstädte’) within

7 Wolfgang Laur, *Historisches Ortsnamenlexikon von Schleswig-Holstein* (2nd revised ed.; Neumünster, 1992).

8 Hans Feldmann, *Baltisches historisches Ortslexikon, Teil I: Estland (einschließlich Nordlivland)*, ed. by Heinz von zur Mühlen (Cologne, Vienna, 1985); *Teil II: Lettland (Südlivland und Kurland)*, ed. by Heinz von zur Mühlen (Cologne, Vienna, 1990).

the Holy Roman Empire, the town was even officially made subordinate to the emperor alone and not to local princes anymore. In many cases, towns evolved from pre-existing settlements, but in the 12th and 13th centuries, many new towns were founded by the local lords, for example in the area bordering the Baltic Sea.

In practice, however, the boundary between a village and a town was fluid: in many instances, a set of privileges was not granted at once, but rather gradually over a longer time period, making it difficult to pin down the exact moment the settlement became a town. In other cases, a charter with town rights has not been preserved or never existed, and the existence of town privileges can only be inferred from characteristics such as the existence of a town seal, burgomaster or town walls, or because contemporary sources refer to the settlement as a town. Some settlements never acquired full town privileges, but nevertheless acquired a town-like character and were seen by contemporaries as town. An example is Leer in East Frisia, a town-like market settlement and important river harbour that gained prominence during the 16th century, but that would only be officially made into a town in 1823.[9] On the other hand, many settlements that were founded as towns remained mere villages in a socio-economic sense. In the county of Holland, town privileges were even granted to islands (Texel, Wieringen) or groups of villages.

The category of settlements inbetween towns and villages, which enjoyed limited privileges but never became full towns, are referred to with terms from both contemporary ('weichbild', 'flecken', 'hakelwerk') and modern scholarly ('minderstadt', 'ackerbürgerstadt') classifications. These have usually been translated as borough in the descriptions in the database. Because it is impossible to make a clear general distinction between all different classes of settlements, it has been chosen to only include a attribute for town, and to explain the choice for classifying a settlement as town or not in the description. There, the user can usually find a short description of the aspects of the character of a settlement.

Due to the important role of towns within the transportation network, it has been chosen to include all towns within the regions covered by the subprojects that have received town privileges before 1650. This means a large addition to the collection of places from *Hansische Handelsstraßen*, since Bruns and Weczerka have only focused on the primary Hanseatic towns, the main trading centres of Hanseatic merchants, and the routes between them. This goes especially for regions at the margins of the Hanseatic area, such as Denmark and the Low Countries.

Leading for the inclusion of towns have been a number of publications that collect information about towns within certain regions. For Germany, including the eastern regions that were ceded to Poland, Russia and the Baltic states after the Second World War, the primary compendium is the *Deutsches Städtebuch*, which has been published in various volumes since 1939.[10] For the regions of Lower Saxony, Schleswig-Holstein, Thuringia, Saxony-Anhalt, Mecklenburg-Vorpommern, Brandenburg, the Saxonian area around Leipzig and the Polish voivodeship West Pomerania, all towns having received town rights before 1650 according to the *Deutsches Städtebuch* were included; information in other regions is still being added.[11] For the present-day Netherlands, the *Repertorium van de stadsrechten in Nederland*[12] has been leading for the inclusion of towns in the

9 Harm Wiemann, “Tausend Jahre aus der Geschichte 800-1823”, in *Leer. Gestern heute morgen*, ed. by F. J. Mueller (Leer, 1973), 25-63.

10 See https://www.uni-muenster.de/Staedtegeschichte/Forschung/Deutsches_Staedtebuch.html

11 Currently, information from the *Deutsches Städtebuch* has been supplied for the towns in the database for the regions of Hesse and Westfalia and the historical provinces of West and East Prussia (nowadays in Poland and Russia). This only goes for the towns included in *Hansische Handelsstraßen*; other towns will be included later.

12 Joost C.M. Cox, *Repertorium van de stadsrechten in Nederland*, Werken van de Stichting tot Uitgaaf der Bronnen van het Oud-Vaderlandse Recht 33 (Oisterwijk, 2012, 2nd ed.), online updated edition at https://www.universiteitleiden.nl/binaries/content/assets/geesteswetenschappen/institute-for-history/repertorium-stadsrechten.pdf (consulted 10 November 2020).

Viabundus database. For Denmark, the selection of towns is mostly based on Kristensen and Paulsen's *Danmarks byer i middelalderen*, along with other works on Danish towns.[13]

Although not every settlement is a town, all towns are settlements. For this reason, the town attribute is always accompanied by the settlement attribute, even if the settlement was founded as a town and did not develop from a preceding settlement.

Toll

In theory, a road or water toll is a fee that had to be paid to the owner of a specific stretch of road or waterway as a contribution to the costs of maintaining it. In the High Middle Ages, however, the toll rights were more and more understood by lords to be an important source of income, whereas the duties of maintaining the road were neglected.[14] Moreover, there existed other forms of fees that travellers had to pay that share many characteristics with tolls and are sometimes hard to discern from them. For example, there was the safe conduct ('Geleit'), which originally was the practice of lords to accompany travellers by armed escorts through their lands. This service developed over time into the paper version, where travellers would be issued a letter in which the lord offered his protection, of course in return for a fee.[15] Because this was an obligatory service, the safe conduct resembled a toll in many aspects. Other transit fees include bridge tolls, ferry fees, cranage (a fee to be paid to use the crane in a harbour) and harbour duties. Tolls could also be levied at certain times only, usually during times in which fairs took place (market toll). Finally, another type were customs, usually levied as a specific percentage of the imported or exported cargo.

Because it is often difficult to discern between the different types of tolls, among others because of a lack of sources, we have chosen to group all transit fees together as tolls and to explain them shortly in the descriptions where appropriate. We have aimed to be exhaustive in supplying all of the known stations for the payment of transit tolls, safe conduct and customs. As other types of fees such as harbour duties, market or ferry fees can be considered to be inherent to the respective attribute (i.e., one can assume always having to pay something for using a harbour or ferry or visiting a fair) and are often not mentioned in the sources, we have not included them systematically, but mentioned them when come across. Not included are local tax payments for consumed goods, such as excise fees on beer and wine and similar taxes, since these are not primarily related to travelling.

Other specific characteristics of tolls often depend on the type of transport and on the identity of the traveller. Certain groups of persons could be exempted from toll payments at a toll station. Usually, these were members of the nobility and the clergy, but inhabitants from specific towns, regions or monasteries could be exempted as well. Moreover, once a traveller had paid toll at a toll station owned by the lord of a territory, he was often exempted from toll payments at the other toll stations he would pass within the territory; in these cases, a leaflet was issued by which it could be proven that toll had already been paid. Next to exemptions for persons, tolls were often levied on specific commodities (e.g. salt, oxen, cloth) or types of transportation (horses, wagons, carts). In places where a navigable waterway existed, the toll could be only levied on vessels or on land traffic or both. A further complication was that tolls often changed hands through wars, sale or heritage, or they were pawned by the owner of the toll.

13 Hans Krongaard Kristensen and Bjørn Paulsen, *Danmarks byer i middelalderen* (Aarhus, 2016); Jørgen Elsøe Jensen, *Danmarks Middelalderlige Byplaner*, 7 vols. (Odense, 1992-2000); Andrén, *Den urbana scenen: städer och samhälle i det medeltida Danmark* (Lund, 1985).

14 Bruns and Weczerka, *Hansische Handelsstraßen*, 40.

15 Ibid.

In the case that information about the specifications described above is available (which often is not the case), it is included in the *Description* field, to give an idea about the type of toll. For the important large toll stations, where much information is available, the specifications are often summarised. At some of these places, more than one toll was levied, which are mentioned separately in the *Description* field. The user is advised to look in the literature or sources cited in the references for a more precise assessment of the toll. Also included are references to extant lists of toll tariffs or available toll registers, since these are valuable sources for the study of traffic flows.

Toll is the only attribute that can be attached to parent as well as child nodes (see Nodes). When attached to a parent node, it is considered to be valid for all of the child nodes as well. This is often the case in towns where the same toll was levied at all town gates. When it is attached to child node, it is only valid when the node itself is passed. This is for example the case in Lüneburg, where a ducal toll was levied at a toll house in the Bäckerstraße in the centre of town.[16] This toll did not pertain to the entire town area, and is therefore attached to a child node of Lüneburg.

Staple

With staple rights, towns and rulers sought to concentrate trade in certain places. Towns with staple privileges had the right to force merchants to unload their wagons or ships and to offer their commodities for sale on the local market for a certain period of time, usually three days. The staple rights could be valid for certain commodities only or for all commodities transported through town. Additional regulations often involved the prohibition of trade between foreigners without the involvement of local merchants, or the obligation to make use of local wagoners or skippers for further transportation of the commodities. Moreover, staple privileges were often connected to a system of prescribed roads ('Straßenzwang') within a certain region, whereby merchants were not allowed to use roads that circumvented the staple town.

In many cases, the geographical situation of staple towns already forced merchants to transship their commodities at certain places or naturally concentrated traffic in a certain place. Examples are harbour towns on the mouths of rivers, where transshipment between sea ships, land transport and river shipping had to take place (e.g. Bremen, Hamburg, Stettin), or where natural barriers prevented continued sailing on a river (e.g. Hann. Münden). It was not unusual that such places already exercised staple-like policies before the staple rights were actually granted. On the other hand, when natural circumstances made it easy to circumvent the staple, we can see that staple privileges were sometimes difficult to enforce. For example, the importance of the staple of Dordrecht, located at the border between the Rhine delta and the North Sea, gradually declined after the flood of St Elizabeth (1421) had inundated the surrounding countryside and the town became located on an island, making it easy to circumvent.[17]

A slightly different type of staple are the staples established by foreign merchants who concentrated their business abroad in one place. Examples are the Hanseatic merchants who established staples in Bruges and later Antwerp in Flanders, or the English company of Merchant Adventurers, who concentrated their business in one German port (at various times Emden, Stade and Hamburg). Because these staples often apply to trade routes outside the current regional extent of the map, they have not been included systematically, although they are noted when come across.

16 Wilhelm Reinecke, *Geschichte der Stadt Lüneburg, Bd. 1* (Lüneburg, 1933), 302-304.

17 Otto Gönnenwein, *Das Stapel- und Niederlagsrecht.* Quellen und Darstellungen zur hansischen Geschichte N.F. 11 (Weimar, 1939), 47-48, 63, 65.

The most important overview of staple privileges within the Holy Roman Empire is Otto Gönnenwein's *Das Stapel- und Niederlagsrecht* from 1939.[18] The information for all staple towns from this work has been incorporated into the Viabundus database, with the exception of towns outside of the covered region (e.g. Vienna). This information has been corrected and supplemented with other sources for the regions covered in the different subprojects.

Next to the *From*, *To* and *Description* fields, the staple attribute also contains the *Duration of stay* field, where the period that merchants had to offer their commodities on the local market is defined in days, which can be used in the calculation of travel times. The value is expressed as a floating point number with one digit after the decimal point. The reason for this is that some staple rights have durations of stay declared in other units than days, e.g. in Stade (3 floods, i.e. roughly 1.5 days). If the *Duration of stay* is unknown or unspecified (null), the Route calculator will assume a duration of 3 days.

Fair

Markets formed the backbone of the economic structure because they provided the primary venues for exchange. They are one of the indicators for the town-like character of a settlement, since they were often granted in privileges. They roughly fall apart in two categories: weekly and annually organised markets (fairs). Weekly markets usually mainly served the exchange of local products within the direct vicinity of the market settlement, whereas fairs often attracted visitors from much further away, and thus were important centres for the long-distance trade. For this reason, fairs have been included in the database. Weekly markets were not, also because evidence for them is often harder to find. The underlying assumption is that many towns will have had a weekly market. On the other hand, fairs were usually, but not always, held in towns: monasteries or pilgrimage destinations, for example, often held fairs connected to religious feasts.

Because fairs not only have a spatial, but also a temporal dimension (they were organised at a certain date each year), it is possible to include a separate description for each fair held in the market settlement, as well as information about its date and duration. Next to a general description of the fair attribute, which has the same fields as the other attributes, a separate relational table includes the information about separate fairs:

Name	**Type**	**Comments**
ID	Integer	A unique identifier
Nodes_ID	Integer	Links the fair to a specific node
Continuation_From_ID	Integer	Links to another entry by the ID field in case a fair is modified, e.g. its duration or its date. A new fair is then added which is marked as a continuation of the old fair. Note that this has implications for the *From* and *To* fields of the two connected fairs.
Name	String	The name of the fair, only if it is known under a specific own name (e.g. “Kieler Umschlag”). In most cases, this field will remain empty.
From	Integer(4)	A year from which the fair exists
To	Integer(4)	A year in which the fair stopped being organised
Description	String	Description of the individual fair. Any general remarks about the market situation of the described node and the relation between the

18 See previous footnote for the full reference.

		various fairs to each other is included in the general *Description* field of the fair attribute of the current node.
Category	String	This field has three options: “local”, “regional” or “interregional”.[19] It describes the economic importance of the fair and its geographical scope. Local fairs are defined as fairs that predominantly serve the economic needs of the surrounding region of the marketplace. Merchants would usually not have to travel for more than a day to arrive at the fair, and the duration was usually limited to one or a few days. Interregional fairs are the large fairs that drew an “international” public, often from a range of hundreds of kilometres. They often lasted multiple weeks. Examples are the fairs of Frankfurt, Leipzig and the herring fairs of Scania.[20] The “regional” category covers everything in between. Of course, it is often hard to distinguish in which category a fair fits, especially if there is no evidence for the place of origin of the visitors. In this case, the duration of a fair is taken as indicator: fairs with a duration of a few days are placed in the local, those over a week in the regional category. The *Category* field is used to filter fairs for display in the fair calendar (see below).
Fields that describe the date on which the fair took place		
Date	String	Three options: “fixed”, “movable” and “unknown”. A fixed date is a date that is each year on the same day. These were usually defined as (a certain number of days before or after) a saint’s day. In many other cases, the date for a fair was set on a movable day, i.e. a day that had a different date each year. In most cases, these are dates that are defined in relation to a Sunday of the Easter cycle. Since the exact date of Easter was related to the moon cycle, these dates took place on a different date each year. Similarly, movable dates are days that are defined as a certain weekday before or after a fixed day, e.g. Monday after St Martin’s Day. The option “unknown” is included for fairs for which it is unknown on which date they took place. In most cases, however, these fairs will only be described in the general description of the fair attribute and not be included as a separate fair.
Fixed_Day	Integer	The day of the month in case that *Date* is set to “fixed” or *Date* = “movable” and *Date_Depends_On* = “Fixed date”.
Fixed_Month	Integer	The number of the month in case that *Date* is set to “fixed” or *Date* = “movable” and *Date_Depends_On* = “Fixed date”.

19 This is a simplified version of the five categories of fairs according to Michel Pauly, „Jahrmärkte in Europa vom 14. bis 16. Jahrhundert. Regionale Untersuchungen und der Versuch einer Typologie“, in Franz Irsigler and Michel Pauly (eds.), *Messen, Jahrmärkte und Stadtentwicklung in Europa / Foires, marchés annuels et développement urbain en Europe* (Trier, 2007), 25-40. Cf. Franz Irsigler, „Messen, Jahrmärkte und Stadtentwicklung in Europa. Mittelalter und frühe Neuzeit“ in the same volume, 22.

20 It should be noted that it has been decided not to discern between the German "Messe" and "Jahrmarkt". Although these are often treated in literature as two different categories, in other languages this distinction is not made, and there is no clear distinction in definition, although "Messe" is usually used for the larger fairs with an international importance. Its use as an analytical concept is therefore limited, and is disregarded in the database. However, fairs described as "Messen" in literature will usually be classified as "interregional".

Weekday	String	In case that *Date* is set to “movable”, this field can contain a name of a weekday (i.e. Monday - Sunday) on which the fair took place before or after the reference date.
Before_After	String	In case that *Date* is set to “movable” and *Weekday* is defined, this field defines whether the fair took place on the selected weekday either “before” or “after” the referenced day.
Date_Depends_On	String	In case that *Date* is set to “movable”, this field indicates which day as reference day to relate the date to. It can be set to “Fixed day” if the referenced day is a fixed day, as in “Monday after St Martin’s Day”, in which case *Fixed_Day* and *Fixed_Month* contain the fixed date. In cases of dates relative to the Easter cycle, this field contains the name of one of the feast days of the Easter cycle, i.e. “Easter” for Easter Sunday, “Ash” for Ash Wednesday, “Ascension” for Ascension Day, “Pentecost”, “Sacramentum” for Corpus Christi, “Sacred heart”, “Cicumded” for Circumdederunt/Septuagesima, “Exurge” for Exurge/Sexagesima, “Esto mihi” for Esto mihi/Quinquagesima, “Invocavit”, “Reminiscere”, “Oculi”, “Letare”, “Judica”, “Palmarum” for Palm Sunday, “Quasimodo” for Quasimodogeniti, “Misericordia”, “Jubilate”, “Cantate”, “Vocem” for Vocem iucunditatis/Rogate, “Exaudi” and “Trinitatis” for Trinity Sunday.
Fields that describe the duration of the fair (can be left blank if unknown)		
Start_Max	Integer	A negative number for the earliest possible day before the set date that the fair could take place. If the duration of a fair is certain or constant, this field remains blank.
Start_Min	Integer	A negative number for the number of days before the set date on which the fair began. If the fair only lasted one day, this field remains blank.
End_Min	Integer	A positive number for the number of days after the set date on which the fair ended. If the fair only lasted one day, this field remains blank.
End_Max	Integer	A positive number for the latest possible day after the set date that the fair could take place. If the duration of a fair is certain or constant, this field remains blank.

The fair calendar

The information from the table with individual fairs is used to compile a calendar with fairs for a specific year and a specific place. It can be accessed from each node with a fair attribute; the year can be set with the time slider. The user will thereupon see a calendar with all the fairs that are of relevance for the selected node in the selected year. The selection of “relevant” fairs is selected based on the following rules: all fairs with the “local” category within a radius of 50km, all fairs of the “regional” category within a radius of 200km and all “interregional” fairs within a radius of 500km. These ranges are displayed on a small map with all displayed fairs as circles of different colours. Given the sometimes difficult categorisation of the fairs in one of the three categories, the

user has the option to change the size of the ranges and thereby influence the selection of relevant fairs.

Bridge

One of the most important factors influencing the course of land routes are bodies of water. In many instances, roads crossed rivers where natural fords existed. If the natural circumstances did not allow the crossing of a river with a ford, bridges or ferries were needed. In the period under consideration, bridges were rare because of the high costs for construction and maintenance. They usually appear near towns that wanted to facilitate traffic, often replacing a previous ford or ferry. However, some bridges were not suited for heavier traffic, which could lead to the co-existence of bridges and fords (such as in Kassel before reconstruction of the bridge in 1342[21]) or ferries (such as in Minden on the Weser river[22]).

Most simple bridges were made from wood: this was the cheapest option, but also the one requiring most maintenance. Moreover, wooden bridges were more likely to be damaged by drift ice in winter. Sometimes the bridge was partly deconstructed to prevent this, becoming unusable in the winter season.[23] More stable – but more expensive – constructions were (partly) made from stone. A third option was the construction of a bridge made by joining floating pontoons or vessels together. Such a bridge was for example built across the Nederrijn in Arnhem in 1603.[24] To pay for the construction and maintenance of a bridge, town authorities often levied a bridge toll on or at the bridge. Where this is known to have been the case, information will be included under the Toll attribute.

Ferry

A ferry is a vessel departing on a regular basis from a permanent location that carried people, cargo and vehicles across the water for payment.[25] According to Sandberg's study of ferries in Zeeland, they can be divided into two categories, the first being the "overzetveren" ('transfer ferries') that sailed to the opposite shore of a body of water, usually across short distances. In their function, they can be compared to or replaced by bridges or tunnels. The other category is formed by the "beurtveren" ('turn ferries'), which followed waterways between two places, sailed on a regular schedule and did not stop at other places along the way. Moreover, single skippers were often privileged with offering their services on a ferry route. The regularity, direct connections and privileges discerned them from other forms of water transport.[26]

Ferries have been incorporated if they formed a connection between long-distance roads. In most cases, these are the "overzetveren" of the first category. Only in some instances, for example in water-rich regions with many islands, such as the Dutch region of Zeeland or the Danish islands, "beurtveren"-like connections have been or will be included as well. Not all ferries have been included: it was not uncommon that illegal or more-or-less tolerated ferries functioned a little upstream or downstream of the ferries acknowledged by the authorities. They could be cheaper than

21 Hugo Brunner, *Geschichte der Residenzstadt Cassel* (Kassel, 1913), 23, 39-40, Tafel 5.

22 Friedrich-Wilhelm Brandt, *Fährmann hol über - zur Geschichte der Fähren der Mittelweser* (Holzminden, 2006), 44-49.

23 This was for example the case in Petershagen on the Weser river: Brandt, *Fährmann hol über*, 96-97.

24 Paul M.M. Klep, „De economische en sociale ontwikkeling 1550-1700", in *Arnhem tot 1700*, ed. by Frank Keverling Buisman and Ingrid Jacobs (Utrecht, 2008), 196-197.

25 Ole Ventegodt, Bjørn Poulsen, Flemming Rieck and Jan Bill, *Dansk søfarts historie, bind 1: Fra stammebåd til skib. Tiden indtil 1588* (Copenhagen, 1997), 167.

26 G.F. Sandberg, *Overzetveren in Zeeland* (Middelburg, 1970), 3.

the official ferries, or provided a short-cut for locals. Some of them will not have been attractive for long-distance travellers, where others may have been a possible alternative.

In most cases, a ferry operated on short distances, e.g. to the opposite shore of a river. In such cases, a single node with the ferry attribute has been added to the database. However, in cases where a ferry had to cross larger bodies of water, e.g. in estuaries or between islands, two nodes with the ferry attribute have been added on both ends of the ferry route, which are connected with a line for which “type” is set to ferry (see Edges data model).

Harbour

A harbour is defined as a place where it is possible to change means of transportation between a land route and a water route. Usually, this was a time-consuming process, especially in the case where commodities would be transshipped from vessels onto wagons and carts or the other way around. To facilitate the transshipment, port structures were built in larger towns with landing piers, fixed quay structures from stone and (floating) cranes for the transshipment of commodities. However, in most river harbours near smaller towns and villages, the natural river shore was often used to fasten the vessels and port structures were absent. Often the use of harbours was connected to the payment of various fees like cranage, customs or payment for the dockworkers. Except in cases where there was an explicit toll connected to the harbour, these fees have usually only been remarked upon in the description.

In many larger towns on the mouths of rivers that functioned as transshipment points between inland waterways and sea routes, there existed multiple harbours, often with specialised functions for sea-going ships or river barges. Examples are the sea ports of Bremen and Hamburg, where three separate harbours could be identified: a harbour front for larger sea-going ships, a landing place for river barges, and a small harbour that connected directly to the market place. In such instances, these separate harbours have been specified; in other cases where the harbour was stretched along a river or sea front, the harbour functions have been summarized in a single node.

Since the Viabundus map at this point focuses on inland travel, harbours for sea-going ships have not been added systematically. In the cases that they have been included, it should be noted that according to the definition above, a harbour attribute is not used to mark roadsteads – sheltered anchoring places where ships could wait before entering the harbour or where commodities from larger ships that could not enter the harbour were transshipped to lighter boats before being brought to land.

Lock

Locks in waterways are important elements of projects by which waterways were made navigable or in the construction of new canals. Locks were constructed to maintain enough water depth for shipping. Usually these were not modern pound locks, but simple flash locks that were opened once enough water had accumulated for a boat to pass. In other instances locks were needed to regulate water levels in a region and were constructed as pound locks to let ships pass. In extension, the lock attribute is also used to describe other kinds of passages for ships constructed in barriers in the waterway, such as mill weirs or dams. Because these barriers forced boats to halt for a certain amount of time, they were often also places were fees had to be paid or commodities were checked. For this reason, locks have been included as a specific attribute in Viabundus.

Edges

The second pillar on which the Viabundus data system rests are the edges: the lines that connect the nodes in the network, representing the pre-modern roads and waterways. Each edge connects two nodes and consists of the spatial geometry of the road (i.e. the course of the road as displayed on the map) as well as additional information about the nature of the connection between the two nodes, such as distance, type of connection or certainty of the reconstruction (see Edges data model below). As with the nodes, the edges are stored in a table in a MySQL database.

The Viabundus map shows the roads most likely taken by long-distance travellers. A selection was made of the roads connecting the most important places within the network: at least all nodes with the attribute Town are connected with edges. Note that this means that the Viabundus map does not display all possible connections between all nodes. For our general understanding of long-distance transport and mobility, a detailed picture of all alternatives is of minor importance, especially with regard to the ones on the microlevel of different roads around towns. The user of the Viabundus map should therefore keep in mind that local roads may have existed that were not included in Viabundus, especially between settlements of minor importance.

Another important issue is the distinction between routes and roads: routes are the connections between two places, whereas roads are the actual physical paths embedded in the landscape that were used to travel these routes. Routes between two places could therefore consist of more than one actual road, the choice for which depended on the mode of transport (by horse, on foot, with a cart or heavy freight wagon), season or weather conditions, elevation, purpose of the journey (e.g. trade-related or pilgrimage) or even habit. Moreover, toll stations or staple privileges could make the use of certain roads obligatory, whereas other roads existed that could be used to circumvent the toll or staple illegally. Sources for travel before the 18th century usually describe the routes taken (i.e. a list of places one passes to get from A to B) instead of the actual roads. Although this is a clear distinction in theory, the attempt to display the routes on a modern map means that they become fixed geographically as a drawn representation of an actual road. Information about seasonality or temporal use of a road may occasionally be found in the *Comment* field of the road segments, but it should be kept in mind that the lines on the map do not necessarily display the exact course of the roads taken and that there might have existed alternative roads between two points that were not included. See the Section Reconstructing premodern roads: sources, methods and challenges for more information.

Edges data model

The edges consist of the road network itself in the form of single polylines. Each of these lines connects two nodes or junctions. These were drawn with a GIS application and stored in a separate database table with the following attributes:

Name	**Type**	**Comments**
ID	Integer	A unique identifier
Geometry	WKB	Contains the edge geometry as single polylines in well-known binary (WKB) format. These are converted into the well-known text (WKT) or GeoJSON formats for downloads.
Type	String	Three options: “land”/”water”/”ferry”. Land routes are roads and paths

		on land; water routes are navigable waterways; ferries are short stretches where land routes are carried across water. Note that the ferry option corresponds with the Ferry attribute in the node table. An edge with type “ferry” therefore ideally connects two nodes that both have the attribute Ferry. See the Ferry node attribute for more details.
Section	String (3)	Indicates the region of the corresponding line segment. Important is that the initially digitised roads from *Hansische Handelsstraßen* are marked with “B-W”; these are displayed in grey on the web map. Other values indicate lines checked for historical accuracy. BBG: Brandenburg; BEL: Belgium; DMK: Denmark; EST: Estonia, Latvia, Russia; HOL: Holstein; MBG: Mecklenburg; NDS: Lower Saxony; NLD: Netherlands; NRW: North Rhine-Westfalia; POM: Pomerania; SLE: Schleswig; SSN: Saxony; THU: Thuringia and Saxony-Anhalt.
Zoomlevel	Integer (1)	A number between 1 and 4 that marks at which level an edge is shown on the map. Edges with zoomlevel 1 are displayed at all times, those with higher number only when zoomed in further. Although usually roads connecting larger towns will receive lower zoomlevel numbers, and zoomlevel 4 is mostly used for local side roads shorter than 2 km, this property should not be equated to a categorisation in primary/secondary/tertiary roads. It has been tried to avoid such a categorisation, as this mostly comprises of a modern interpretation of the road system. The zoomlevel property is therefore ignored by the Route calculator.
Certainty	Integer (1)	A number between 1 and 3 that marks the accuracy of reconstruction. 1: very certain; the edge drawn is exactly at the location of the pre-modern road. Used almost exclusively inside towns where the pre-modern street plan is preserved. 2: mediocre; the edge drawn is more or less at the location of the pre-modern road. Due to the unpaved character of pre-modern roads and difficulties in their reconstruction (see the following section below), this is the case in most instances. 3. uncertain: a road is known from (written) sources, but cannot be easily reconstructed with later maps, or a number of parallel tracks are visible on the map between which it is impossible to discern a main road. This is often the case in regions where the landscape has changed considerably in modern times (e.g. industrial regions) or on sandy terrain where road bundles develop easily. These edges are displayed with a dashed line on the map. Additionally, all initially digitised roads from *Hansische Handelsstraßen* that have not yet been checked for historical accuracy have been marked with certainty 3. These roads are additionally displayed in grey.
Length	Integer	The length of the edge in metres. Used for routing calculations.
Comments_ID	Integer	This field links to a table with comments, which makes it possible to include short descriptions, remarks and literature references to specific stretches in pop-ups on the map.

From_Node	Integer	The ID number of the Nodes table that connects to the start of the line segment.
To_Node	Integer	The ID number of the Nodes table that connects to the end of the line segment.

Reconstructing premodern roads: sources, methods and challenges

As described above, drawing lines on a map to represent premodern travel routes is a challenging task. The main problem is that the abstract visualisation of spatial reality in the form of a map as we know it today gradually developed in the early modern period. Before, maps were more or less symbolic representations of the world and were certainly not used by travellers.[27] The sources we have for premodern routes therefore predominantly have a textual character, usually in the form of itineraries, i.e. lists of places that were visited by travellers such as pilgrims or lords. Another type of evidence are letters and accounts, for example of town councils who sent out envoys, in which we can sometimes read where these envoys rested, ate or drank, paid tolls and took ferries while moving to their destination.[28] These places are indicated by points on the map (see Nodes).

In order to map the roads connecting these points, we must resort to the first detailed modern maps with distances measured with triangulation, which first appear in the 18th century. Although the first maps of towns with their road systems start to appear at the turn of the 16th century, they are often simplified or idealised and reflect a modern idea of accurateness only to a limited degree. Moreover, they only shows the roads within town and in its direct vicinity. By contrast, maps of larger areas often do not show the roads at all or only very schematically, resembling written itineraries more than actual maps. Only in the second half of the 18th century, detailed triangulated maps of regions were first drawn, usually with a military purpose. Although these have a number of fixed measured points, the landscape in between them can be heavily deformed, making it difficult to use them as a basis for a one-to-one reconstruction of the roads, even when they are well georeferenced. In the 19th century, well-measured modern maps are available for this purpose, but by this time the landscape had started to change considerably due to industrialisation, cultivation of marginal lands and the construction of railroads, so that they hardly reflect the pre-modern situation anymore.

27 For cartography in the Middle Ages, see J.B. Harley and David Woodward (eds.), *The History of Cartography, Volume 1: Cartography in Prehistoric, Ancient and Medieval Europe and the Mediterranean* (Chicago 1987).

28 Bruns; Weczerka, *Hansische Handelsstraßen*, 88-93. See also Dieter Neitzert, *Göttinger Boten und Gesandte. Reichweite und Intensität städtischer Kommunikation zwischen 1400 und 1450* (Bielefeld 2019).

Map of Doetinchem by Jacob van Deventer (16th century) and the region around Herentals on the map Tertia Pars Brabantiae by Joan Blaeu (1665).

Archaeology may provide additional evidence for mapping premodern roads.[29] Traces in the landscape such as holloways, boardwalks, remains of pavement or remains of bridges are known frequently from many regions. However, their interpretation comes with a number of problems. For example, since they often concern fragments or short stretches, it is hard to connect remains of a road to a certain route or to decide whether it was a locally used road or one of (supra-)regional importance. Holloways are most pronounced on steep slopes, where there is the most erosion, which usually only concerns a small part of the route. In many areas, remains have been built over or disturbed. Moreover, in the absence of additional finds on or next to the road, it is often impossible to date the remains to a certain period. Helpful tools are further provided by modern techniques such as laser scans of the elevation (LiDAR), which can reveal creases in the terrain, or satellite imagery, which can reveal structures in the soil based on colour differences in the vegetation, especially in dry periods, both possibly pointing at former roads.

A further complication is the state of premodern roads: with only a few exceptions, roads were unpaved and unplanned. Most had developed naturally and had been used for centuries by custom. Lords had little interest in maintaining the roads, and roads were paved only in some circumstances, usually within or in the direct vicinity of larger towns.[30] Another exception were dikes and causeways in the lowlands and marshy areas, which were constructed by the authorities and protected the roads against flooding. Where dikes and the building structure in towns kept the roads in place, in most other places it was easy to deviate from the beaten track. If roads became unusable because of wet weather or heavy use, travellers often chose a track next to the road, leading to the development of wide bundles of parallel tracks, especially in flat sandy terrain without many obstacles, such as heather areas (for example the Lüneburg heath or the Veluwe in the duchy of Guelders[31]). Similarly, the means of authorities to fix the course of rivers as waterways were limited, leaving room for natural changes in the course, depth and water carriage of streams. Only from the 18th century onwards, with the planned establishment of paved highways, post roads, the building of canals and the straightening of existing river beds, the situation gradually changed and the location of roads and waterways became more fixed.

29 See the blog post of Nina Dengg, “What did medieval roads look like?”, *The Viabundus blog*, 11-1-2021 (https://www.landesgeschichte.uni-goettingen.de/roads/viabundus/2021/01/11/what-did-medieval-roads-look-like/#more-528).

30 Bruns and Weczerka, *Hansische Handelsstraßen*, 42-44.

31 Frits H. Horsten, *Doorgaande wegen in Nederland, 16e tot 19e eeuw. Een historische wegenatlas* (Amsterdam, 2005), 44-45; Bruno Ploetz, Überlandfernverkehr im Gebiet des Fürstentums Lüneburg, *Lüneburger Blätter* 11/12 (1961), 67-148.

For the reasons sketched above, the reconstruction of premodern roads usually follows the following method: the written sources supply the points (nodes) that are passed on a route. The edges between them are drawn according to the earliest available accurate 18th-century maps, with the assumption that their course must not have changed much over the centuries, with the use of 19th-century maps to map them more precisely. Where possible, additional archaeological or geographical evidence may be used. Even so, it is sometimes very difficult to map a connection between the points known from the written sources accurately. For this reason, the accuracy level for the reconstruction of each road segment is included in the database (see Edges data model), with uncertain reconstructions shown as a dotted line on the map. Moreover, one should keep in mind that a reconstruction of roads on a modern map is first and foremost a tool for those interested in history and does not necessarily reflect the realities of pre-modern travel.

Wismar on the Schmettau map of Mecklenburg-Schwerin (1788-1793)

Regional sources

In most occasions, the same sources are used for the reconstruction of all roads and waterways within a certain region. For this reason, the use of direct references to sources similar to the nodes database is absent for the edges, with the exception of comments for single edges (see Edges data model). Instead, the sources (besides Bruns and Weczerka's *Hansische Handelsstraßen*) used for the reconstruction of the roads and waterways for each region have been listed below.

Germany

For the street network in the modern German states of Lower Saxony (Niedersachsen), Thuringia (Thüringen), Saxony-Anhalt (Sachsen-Anhalt) and Schleswig-Holstein, extensive research has been carried out. For the states of Mecklenburg-Vorpommern and Brandenburg, the roads included in *Hansische Handelsstraßen* have been checked for historical accuracy with the help of historical maps, and additional routes were included to connect all towns before 1650. The street network in North Rhine-Westfalia (Nordrhein-Westfalen) and parts of Saxony (Sachsen) largely remains limited to the roads included in *Hansische Handelsstraßen*, which have been corrected for historical accuracy.

Lower Saxony

The state of the art in research on pre-modern roads in the current state of Lower Saxony is very uneven. The most accurate reconstructions of pre-modern roads upon a modern map appeared in the series *Historisch-Landeskundliche Exkursionskarte / Regionalkarte zur Geschichte und Landeskunde von Niedersachsen* of the Institut für Historische Landesforschung at the University of Göttingen, which have appeared from 1964 onwards. However, most of the 28 volumes that have appeared to date cover the southern part of the state, which is therefore well-researched. Much of these reconstructions are based on the publications of Dietrich Denecke, *Methodische Untersuchungen zur historisch-geographischen Wegeforschung im Raum zwischen Solling und Harz. Ein Beitrag zur Rekonstruktion der mittelalterlichen Kulturlandschaft*, Göttinger geographische Abhandlungen 54 (Göttingen, 1969) and Albert Herbst, *Die alten Heer- und Handelsstraßen Südhannovers und angrenzender Gebiete* (Göttingen, 1926).

For the area north of Hannover and Braunschweig, pre-modern roads have received much less attention. Exceptions are Bruno Ploetz, "Überlandfernverkehr im Gebiet des Fürstentums Lüneburg", *Lüneburger Blätter* 11/12 (1961), 67-147, for the old roads around Lüneburg, and Herbert and Inge Schwarzwälder, *Reisen und Reisende in Nordwestdeutschland: Beschreibungen, Tagebücher, Briefe, Itinerare und Kostenrechnungen, Bd. 1: Bis 1620* (Hildesheim, 1987), for travel accounts of pre-modern travellers in northwestern Germany. A second volume of the latter publication with sources after 1620 was regrettably never published. Unlike the publications about southern Lower Saxony, these publications lack detailed reconstructions on a modern map.

For these reasons, the reconstruction of the road network in southern Lower Saxony in *Viabundus* is largely based on the literature mentioned above, whereas for the northern part, the publications of Bruns and Weczerka, Ploetz and Schwarzwälder have been used as guidelines. In a next step, the most likely course of the pre-modern roads has been traced on 18th-century maps, which could then be transferred - often with the intermediate help of 19th-century maps - to the modern situation. These used maps have been listed below.

- Arnoldt, Hans-Martin et al. (ed.), *Die topographisch-militärische Karte des Bistums Hildesheim von 1798*, Veröffentlichungen der Historischen Kommission für Niedersachsen und Bremen 218 (Göttingen, 2015).
- Arnoldt, Hans-Martin; Casemir, Kirstin; Ohainski, Uwe (eds.), *Die Gerlachsche Karte des Fürstentums Braunschweig-Wolfenbüttel (1763-1775)*, Veröffentlichungen der Historischen Kommission für Niedersachsen und Bremen 235 (Hannover, 2006).
- Colson, Philip Ernst, *Carte vom Amt Meppen* (1773-1777) (Faks.-Ausg. Osnabrück, 2005).
- Elmshäuser, Conrad, *Bremen und sein Landgebiet (1748) von Johann Daniel Heinbach (1694-1764)*, Kleine Schriften des Staatsarchivs Bremen 56 (Bremen, 2017).
- Henninger, Wolfgang; Kappelhof, Bernd; Schumacher, Bernd (eds.), *Die große handgezeichnete Campsche Karte von Ostfriesland von 1806*, Veröffentlichungen der Historischen Kommission für Niedersachsen und Bremen 226 (Hannover, 2005)
- Hoffmann, Christian (ed.), *Die geographische Karte des Niederstifts Münster von Carl Wilckens*, Veröffentlichungen der Historischen Kommission für Niedersachsen und Bremen 310 (Göttingen, 2021).
- *Kurhannoversche Landesaufnahme des 18. Jahrhunderts* (1764-1786), repr. Niedersächsisches Landesverwaltungsamt, Landesvermessung (Hannover, 2003).
- Le Coq, Carl Ludwig von, *Topographische Karte von Westphalen* (1796-1813), online at http://www.westfaelische-geschichte.de/web828 (consulted 9 December 2020).
- Nistal, Matthias (ed.), *Die Oldenburgische Vogteikarte 1790/1800*, Veröffentlichungen der Historischen Kommission für Niedersachsen und Bremen 200 (Hannover, 2000).

Saxony-Anhalt, Thuringia

The state of pre-modern roads in Saxony-Anhalt and Thuringia has stirred some interest in recent years. First and foremost, Pierre Fütterers work *Wege und Herrschaft*[32], which already included detailed reconstructions of early medieval road systems, has to be mentioned. It is the basis for several of the main road connections included in Viabundus. It also includes several regional connections, which made the task more one of reducing the ample suggestions provided. With the gradual rise of trading centres in the region such as Erfurt and Leipzig, new road systems emerged in the course of the 14th to 17th centuries, which connected the towns with Nuremberg in the south and the Hanseatic ports in the north and were not considered in Fütterer's work. For these routes, several works have been published on regional road systems, which provide the main foundation of the reconstruction in Thuringia and Saxony-Anhalt.[33]

In other cases, the wide arrangement of historical maps provided in the *Deutsche Fotothek* by the Sächsische Landesbibliothek - Staats- und Universitätsbibliothek Dresden[34], which contain numerous regional maps from the 17th and later centuries, helped to get an idea of medieval road connections.[35] In cases where no map from the 17th or 18th century could give an idea on how some nodes were connected to the wider road network, maps from the early 19th century were used, but such roads have always been marked at a low certainty.

Especially in the mountainous regions such as the Thüringer Wald or the Harz, data from digital terrain models were used as supplements to determine accurate reconstructions of historical roads. Some online-viewing tools such as the *Geoportal Thüringen*[36] or the *Sachsen-Anhalt Viewer*[37] have implemented LiDAR-scanned terrain models on which holloways ("Hohlwege") can be seen. These cannot be used by themselves, however, since the existence of a holloway alone does not allow any assertions on its age and some of the holloways only developed in modern times.

Water routes have largely been reconstructed according to Martin Eckoldt's (ed.) *Flüsse und Kanäle*.[38] Since the courses of rivers have mostly been sketched in historical maps at best, they are not necessarily best suited to reconstruct the old waterways. The historical course of the Elbe around Magdeburg has been reconstructed in detail in the *Mitteldeutscher Heimatatlas*,[39] other parts have been reconstructed according to regional literature and abandoned meanders that can still be seen today. Later maps may also show more accurate river courses, but due to considerable water engineering in the 18th and 19th century, some research is required to determine whether this course still represents the medieval situation.

More detailed information about the methods and sources for the sub-project Saxony-Anhalt can be found in the separate documentation file.

32 Pierre Fütterer, *Wege und Herrschaft. Untersuchungen zu Raumerschließung und Raumerfassung in Ostsachsen und Thüringen im 10. und 11. Jahrhundert* (Regensburg, 2016).
33 See literature provided in the documentation of Thuringia and Saxony-Anhalt.
34 http://www.deutschefotothek.de.
35 For a list of the maps used within the Deutsche Fotothek please also see the documentation on Thuringia and Saxony-Anhalt.
36 www.geoproxy.geoportal-th.de/geoclient
37 https://www.lvermgeo.sachsen-anhalt.de/de/startseite_viewer.html
38 Martin Eckoldt (ed.), *Flüsse und Kanäle. Die Geschichte der deutschen Wasserstraßen* (Hamburg, 1998).
39 Landesgeschichtliche Forschungsstelle für die Provinz Sachsen und für Anhalt (ed.), *Mitteldeutscher Heimatatlas* (Magdeburg 1935-1942).

Schleswig-Holstein

The street network in the former duchies of Holstein and Schauenburg (roughly the southern part of the current state of Schleswig-Holstein) has been reconstructed and refined with the help of the following 18th-century maps:

- Varendorff, Gustav Adolph von, *Topographisch-militärische Charte des Herzogtums Holstein* (1789-1796), repr. Landesvermessungsamt Schleswig-Holstein (Kiel, 1996).
- *Kurhannoversche Landesaufnahme des 18. Jahrhunderts* (1764-1786), repr. Niedersächsisches Landesverwaltungsamt, Landesvermessung (Hannover, 2003).

The former duchy of Schleswig (the northern part of Schleswig-Holstein) has been reconstructed as part of the Danish sub-project using the sources and methods listed there.

Mecklenburg-Vorpommern

For the historical duchy of Mecklenburg, the following maps were consulted:
- Wiebeking, Carl Friedrich von, *Historischer Atlas von Mecklenburg, Sonderreihe: Wiebekingsche Karte von Mecklenburg um 1786: originalgetreuer Abdruck in 4 Farben*, ed. by Franz Engel (Cologne, 1961-1969).
- Schmettau, Friedrich Wilhelm Karl von, (ed.), *Topographische, Oeconomische und Militairische Charte des Herzogthums Mecklenburg-Schwerin und des Fürstentums Ratzeburg* (1788-1793), online at mapire.eu (consulted 9 December 2020).
- Wiebeking, Carl Friedrich von; Friedrich Wilhelm Karl von Schmettau, *Historischer Atlas von Mecklenburg, Sonderreihe: Schmettausche Karten von Mecklenburg-Strelitz: um 1780*, ed. by Franz Engel (Cologne, 1963).
These maps are available in a digitised georeferenced version at the *Geodatenviewer GDI-MV*[40] of the Landesvermessung und Geobasisinformation Mecklenburg-Vorpommern.

For the eastern part of Mecklenburg-Vorpommern, historically belonging to the duchy of Pomerania:
- Schmettau, Friedrich Wilhelm Carl von, *Historischer Atlas von Pommern, Sonderreihe: Schmettausche Karte von Pommern (um 1780)*, ed. by Franz Engel (Cologne, 1964-1967).
- 18th-century maps of Swedish Pomerania (Svenska Pommern) in the Swedish Riksarkivet, SE/KrA/0402/19/B. These are available online at https://sok.riksarkivet.se/arkiv/XIWFsel5L4Ag7cKhdnjss1.

Brandenburg

The street network in the largest part of Brandenburg has been reconstructed with the help of the Schmettau maps of Brandenburg (1767-1787, Staatsbibliothek zu Berlin - Stiftung Preußischer Kulturbesitzt, available online at Brandenburgviewer[41] of the Landesvermessung und Geobasisinformation Brandenburg). For the area of Niederlausitz: *Lusatiae inferioris tabula chorographica, secundum statum recentissimum delineata et edita curis Homannianorum Heredum. Norimbergae, Anno 1768*; for the region around Elster: Petrus Schenk, *Accurate Geographische Delineation derer zum Sæchsischen Chur Creisse Gehörigen Aemter Liebenwerda und Schlieben*, (Amsterdam, 1753).

40 http://www.gaia-mv.de/gaia/gaia.php, consulted 3-8-2022.
41 https://bb-viewer.geobasis-bb.de, consulted 1-11-2021.

North Rhine-Westfalia

The roads from *Hansische Handelsstraßen* in the modern German state of North Rhine-Westfalia have been drawn and refined according to Le Coq's map of Westfalia (see Lower Saxony), as well as the map of the Rhinelands by the French geographer Jean Joseph Tranchot (1801-1814, continued by Karl von Müffling until 1828) and the *Preußische Uraufnahme* (1836-1850). The latter two are georeferenced and available at the geographical data system of Northrhine-Westfalia (TIM-online). Further use has been made of the map *Descriptio Agri Civitatis Coloniensis* by Joan Blaeu (1662) for the roads around the city of Cologne.

Saxony

The street network in a large part of modern Saxony was reconstructed with the help of the *Meilenblätter von Sachsen*, which were created between 1780 and 1825,[42] as well as the reduced version of the maps published as the *Topographischer Atlas von Sachsen* by Jakob Andreas Hermann Oberreit in four volumes between 1836 and 1860.[43]

Netherlands

For roads within the borders of the present-day Netherlands, we could build on a solid basis of earlier research performed by Frits Horsten (published in 2005), which has been digitized and improved within the project "The Dark Age in the Lowlands in an interdisciplinary light" (Utrecht University / Cultural Heritage Agency (RCE) / University of Groningen) (published in 2016).[44] These files have been kindly shared by the RCE with the Viabundus project.[45] The roads on the Viabundus map largely correspond to the road system as reconstructed by Horsten and the RCE. The system of primary roads they reconstructed reflects the situation around the period 1575-1600. For the Viabundus map, remarks on changes in the road system over time have been occasionally added to road segments.

The reconstruction of the pre-modern road network of the Netherlands by Horsten is based on regional ("gewestelijke") maps from the period 1621-1650, combined with maps made by Christiaan Sgrooten around 1573 and 1592. Subsequently, Horsten used the *Topographic and Military Map of the Kingdom of the Netherlands* (TMK) of 1850 to localize these premodern roads on a modern map. This map is generally considered highly complete, accurate and of uniform quality. Horsten determined the main roads by focussing on connections between larger towns.[46]

42 A digitised version is available at the *Deutsche Fotothek*: https://www.deutschefotothek.de/cms/kartenforum-sachsen-meilenblaetter.xml.

43 A digitsed version is available at the *Deutsche Fotothek*: https://www.deutschefotothek.de/documents/obj/70302462 as well as at maps.arcanum.com.

44 Horsten, *Doorgaande wegen*. The research for Horsten's project was based on data collected by mr. J. Swart, and closed off in 1992. The work itself was published in 2005. Van Lanen, Rowin, *Changing ways. Patterns of connectivity, habitation and persistence in Northwest European lowlands during the first millennium AD*, Utrecht Studies in Earth Sciences 137 (Utrecht, 2017); Van Lanen, Rowin J.; Groenewoudt, Bert J.; Spek, Theo; Jansma, Esther, 'Route persistence. Modelling and quantifying historical route-network stability from the Roman period to early-modern times (AD 100-1600): a case study from the Netherlands', *Archaeological and Anthropological Sciences* 10 (2018), 1037-1052 (Published 18 November 2016, Issue date August 2018); Kosian, Menne; Van Lanen, Rowin; Weerts 2016, https://www.landschapinnederland.nl/verstedelijkingskaart (consulted 12 August 2020).

45 For practical reasons, we will refer to the files resulting from the cooperation between Utrecht University, the RCE and University of Groningen as the map from the RCE. The map can be consulted on the RCE website; Rowin van Lanen, whose dissertation research was central to the digitization and refinement of Horsten's data, is currently working at the RCE.

46 Horsten, *Doorgaande wegen*, 9-46.

Notable for the Viabundus project, this means that some roads connecting smaller towns were not covered by Horsten. Moreover, some roads mentioned by Bruns and Weczerka may not be found on his reconstruction, for example the road between Bocholt and Sittard via Stokkem. In the Viabundus project, we have chosen to incorporate these roads in both cases, if necessary with a remark on the period for which their use can be demonstrated.

By carefully comparing the road system reconstructed by Horsten with the roads indicated on the TMK 1850 and maps of Jacob van Deventer (made ca. 1545-1575), Van Lanen and others were able to refine the road system for the RCE map. They indicated that these alterations mainly concerned local refinements. Larger adjustments were especially made in Friesland, where main roads were missing, and the roads between Geertruidenberg and Zevenbergen and between Rotterdam and Zevenbergen.[47] Based on the maps of Van Deventer, the map of the RCE also contains the street plan within towns. These streets have not completely been incorporated in the Viabundus map, but they can be found on the *Kaart van de verstedelijking* (Map of Urbanisation)[48] online.

In some instances, we have chosen to deviate from the routes of the RCE map, especially where it concerns areas that were heavily changed by inundations before 1600. This especially goes for the province of Zeeland, which was hardly covered by Horsten. The makers of the RCE file connected the towns in this area via the dikes, but these are often considerable detours, where more direct routes must have existed. For this reason, additional literature was used to reconstruct the roads in this region. For the regions of Zeeuws-Vlaanderen, the reconstruction of roads before the inundations of the late 16th century was based on the historical geographical works of Gottschalk.[49] For the rest of the province, the ferry connections between the islands were the central nodes next to the towns, and these have been entered according to Sandberg's study of ferries in Zeeland.[50] The roads between these nodes were then drawn according to the TMK, Christiaan Sgroten's map of the Schelde region from 1573 and the map of the island of Walcheren by Joan Blaeu from 1659. In other areas, roads were added as well that disappeared before 1600, such as the roads Amsterdam-Haarlem via Sloten and Hillegom-Aalsmeer that disappeared in the Haarlem Lake in 1509 and 1477 respectively,[51] and the road between Dordrecht and Geertruidenberg through the Grote Waard that was flooded in 1421.[52] In the provinces of Drente and Friesland, the road Kuinre-Oldemarkt-Donkerbroek from the RCE map, that was already marked as problematic by Horsten because of its course through a moor,[53] has been replaced by a road from Steenwijk to Donkerbroek, which was located on a sand ridge and is indicated on Cornelius Pijnacker's map *Drentia Comitatus* (1664) as "Vriesche Weg" ('Frisian road').

Waterways were especially important in the northern and western parts of the Netherlands, but were not included in the RCE map. Next to the big rivers, these have been added according to specialist literature. These can be divided into four groups. The first is the waterways in the county

47 Kosian, M.C.; Van Lanen, R.J.; Weerts, H.J.T., *Een nieuwe kaart van Nederland in 1575* (Amersfoort 2016), 19-21.

48 https://www.landschapinnederland.nl/verstedelijkingskaart (consulted 12 August 2020).

49 M.K.E. Gottschalk, *Historische geografie van westelijk Zeeuws-Vlaanderen. Deel 1: Tot de Sint-Elisabethsvloed van 1404* (Assen, 1955); *Deel 2: Van het begin der 15e eeuw tot de inundaties tijdens de tachtigjarige oorlog* (Assen, 1958); *De Vier Ambachten en het land van Saaftinge in de middeleeuwen. Een historisch-geografisch onderzoek betreffende Oost Zeeuws-Vlaanderen* (Assen, 1984).

50 G.F. Sandberg, *Overzetveren in Zeeland. Zevenhonderd jaar vervoer te water* (Middelburg, 1970).

51 Petra J.E.M. van Dam, "De tanden van de waterwolf. De rol van turfwinning bij het ontstaan van het Haarlemmermeer in de vijftiende eeuw", *Tijdschrift voor Waterstaatsgeschiedenis* 5 (1996), 81-91: 83-84; J.C. Ramaer, *De omvang van het Haarlemmermeer en de meren waaruit het ontstaan is, op verschillende tijden vóór de droogmaking* (Amsterdam, 1892), 10-11, 80-81.

52 Rombert Stapel, "Reconstruction of the Grote Waard (Holland) prior to the St Elisabeth's Flood (1421)", IISH Data Collection, V1 (2021). https://hdl.handle.net/10622/XZAHCX.

53 Horsten, *Doorgaande wegen*, 107 no. 5.

of Holland, including the major north-south artery of the “route binnendunen” between Spaarndam and Gouda.[54] Second, the waterways in western Friesland have been mapped according to the Schotanus-Halma atlas of Friesland (1718),[55] which were cross-checked with Gildemacher’s compendium of Frisian water names,[56] to check if they already existed in the period 1350-1650. Third, the small rivers east of the IJssel.[57] Fourth, the canals built or equipped for regular barge services for passenger transportation (“trekvaarten”) in the 17th century were included that came into existence before 1650.[58]

Denmark

The street network of Denmark including the duchy of Schleswig, currently part of Germany, was reconstructed using the oldest triangulated large-scale maps of the Royal Danish Academy of Sciences and Letters (“Videnskabernes Selkabs Kort”) that were compiled between 1762 and 1820. Point of departure are the detailed concept maps of the Academy (scale 1:20.000) and not the printed version (scale 1:200.000). All roads depicted as main roads on the maps were included in Viabundus, and were directly drawn on basis of the georeferenced historical maps. Later corrections were made for the street networks within towns and for the area around Copenhagen, which has seen significant development in the 17th and 18th century. Corrections were also made for the Schleswig North Sea coast, where much land reclamation has been undertaken over the centuries. This goes especially for the dating of roads within reclaimed areas.[59]

The Danish road network also included the Swedish region of Scania (Skåne), which belonged to Denmark until 1658 and is therefore not included on the Academy maps. In this region the roads were drawn with the help of the digitised historical maps of Lantmäteriet (https://historiskakartor.lantmateriet.se), especially the 1712 map of Skåne by Johan Bosson Kempensköld (L11). These were not drawn with a georeferenced version, but by comparing the roads with a modern map.

Belgium

The street network for the modern Belgian regions of Flanders and a part of Wallonia as included in *Hansische Handelsstraßen* has been checked for historical accuracy, according to the Ferraris maps of the Austrian Netherlands from the 1770s, as well as the *Carte topographique de la Belgique* by Philippe Vandermaelen (1846-1854). Additionaly, parts of the Belgian street network has been more extensively mapped in the context of the work on the Netherlands. This goes for the roads in the border region with the Netherlands, i.e. those connecting Bruges via Antwerp with Maastricht and their side roads into the Netherlands. Moreover, many of the navigable waterways connecting the towns of Bruges, Gent, Antwerp and Brussels have been mapped. For the waterways in the region around Gent, additional use was made of the 17th-century map *Nobilibus Amplissimisq. Dominis D.*

54 Bart Ibelings, “De route 'binnendunen'. De scheepvaartroute langs de Goudse sluis en tol, de Wassenaerse Gouwesluis en de Spaarndammertol (13e - 16e eeuw)”, in D.E.H. de Boer e.a eds., *Vander Rekeninghe. Bijdragen aan het symposium over onderzoek en editieproblematiek van middeleeuws rekeningmateriaal 1997* (Den Haag, 1998), 221-255; Walther Vogel, “Die Binnenfahrt durch Holland und Stift Utrecht vom 12. bis 14. Jahrhundert”, *Hansische Geschichtsblätter* 36 (1909), 13-36.

55 Online at https://www.frieslandopdekaart.nl/kaarten/categorie/3-Schotanus-Halma-atlas-1718.

56 K.F. Gildemacher, *Waternamen in Friesland* (Leeuwarden, 1993).

57 G.J. Schutten, *Varen waar geen water is. Reconstructie van een verdwenen wereld. Geschiedenis van de scheepvaart ten oosten van de IJssel van 1300 tot 1930* (Hengelo, 1981).

58 Jan de Vries, *Barges and Capitalism. Passenger Transportation in the Dutch Economy, 1632-1839* (Utrecht, 1981); Meindert Schroor, “Trekvaarten in Friesland en Groningen”, *Noorderbreedte* (30-11-1990), 20-23.

59 Based on Harry Kunz; Albert Panten, *Die Köge Nordfrieslands* (Bräist/Bredstedt, 1997).

Georgio de la Faille Toparchae de Neulle etc. Praetori Totiq. collegio Supremae curiae feudalis regiae Veteris burgi Gandensis Hanc Veteris Burgi novam tabulam by Joan Blaeu.

Poland: West Pomeranian Voivodeship

The roads in the historical duchy of Pomerania, a large part of which is nowadays located in the Polish voivodeship of West Pomerania, have been corrected for historical accuracy with the help of the Schmettau maps of Pomerania, see Mecklenburg-Vorpommern.

Estonia, Latvia and Russia

The roads from *Hansische Handelsstraßen* in the modern states of Estonia, Latvia and the adjoining Russian region around Velikiy Novgorod have been drawn according to the 1872 map of the Russian Empire, which is included in the map “Europe in the XIX. Century” at mapire.eu.[60]

Route calculator

Since the Viabundus system has been conceived as a network model, it is possible to make a least-cost path analysis. A simple path analysis tool has been included in the form of a route calculator or journey planner. It is based on a Dijkstra”s algorithm for finding the shortest path in a network, inspired by the routing system used by the *ORBIS* digital map of the Roman Empire (2012).[61] The Viabundus routing engine produces the shortest path between two nodes based only on distance, with the option to calculate only using land or water ways or both. Changes between modes of transportation are accounted according to the following rules:
- When the option “only water” is selected, the routing algorithm still includes land routes for up to 1 km removed from the water. This is done because most central nodes are not located at the waterfront and are only connected with the water network via another (child) node. The algorithm would otherwise not find the starting or destination point. Moreover, it allows for including transshipment points where cargoes would have to be transshipped from one vessel to another, for example in staple ports (see the example of Hann. Münden above).
- When both land and water routes are selected, the change between them can only take place at a node with the Harbour attribute.

Next to the shortest distance, there is the option to calculate the fastest route between two places, although this currently only works for land routes. Travel times can be calculated for various modes of travel, each of which have been set to a speed in km/h and a maximum daily limit in km.[62]

Type	Speed (km/h)	Daily limit (km)
Pedestrian / commercial transport (wagons/carts)	5	35
Horseback (normal speed)	6	50

60 https://mapire.eu/en/map/europe-19century-secondsurvey (consulted 19. January 2021).
61 See Walter Scheidel, Elijah Meeks and Jonathan Weiland, *ORBIS: The Stanford Geospatial Network Model of the Roman World* (May, 2012), url: https://orbis.stanford.edu/orbis2012/ORBIS_v1paper_20120501.pdf (consulted 19 January 2021).
62 Based on the table of travel speeds in Norbert Ohler, *Reisen im Mittelalter* (München, 1998), 141 and the documentation of *ORBIS*: https://orbis.stanford.edu/orbis2012/#building (consulted 12 March 2021).

Messenger (fast, with horse relays)	14	120
Ferry	5	-

Moreover, additional time is added when passing certain nodes. Staple rights often included the forced stay of a certain duration, during which merchants were forced to offer their commodities on the local market. For this reason, the number of days as registered in the *Duration of Stay* field in the Staple attribute is added to the travel time in the case of commercial travel. In case the *Duration of Stay* field is empty, it is assumed to be three days. Additional travel time is added when the route crosses the water with a ferry: +1h in total for (un)loading the ferry on each shore.

Of course, this presents a heavily simplified and generalized version of actual travel times, which would depend on numerous other factors, such as seasonality, weather conditions, day length, physical condition of travellers and animals and the political situation (wars and borders). Many of these factors are impossible or very difficult to reconstruct and have therefore not been taken into account. Slope and elevation of the road, a factor that is of significant influence on the speed of travel in mountainous regions, has not been taken into account, but it is planned to be included in a future version of Viabundus. A further issue that should be kept in mind is that pre-modern travellers of course did not use maps or navigation algorithms for wayfinding, and that the path produced by the routing system therefore does not necessarily present the path most likely taken by a premodern traveller.[63]

Especially for water-based travel, actual travel times fluctuated widely.[64] Downstream travel was closely linked to the flow speed of a river, which fluctuated with the water carriage throughout the year, and is hard to reconstruct since the flow speed of rivers has changed a lot due to modern canalisation projects. Upstream, vessels were usually towed, which was a lot slower. On canals, on the other hand, the flow direction of the waterway was only of minor importance. Moreover, seasonal changes often influenced the navigability of rivers, which could become impossible to navigate in winter (because of ice) or in summer (because of low water levels). On lakes and in estuaries and river deltas, sailing must have been the preferred way of navigating the waters, with sailing times depending on the wind situation. Since the primary aim of Viabundus is the mapping of land routes, a calculation of travel times for water transport requires additional research, and has therefore been left out for the time being.

Generally, it should be noted that the route calculator remains in a primary stage of development and that the quality of its results depends heavily of the quality of the road reconstruction and the quantity of elements included in the nodes database. These elements differ for different regions. A more sophisticated development of the routing system and further refinement and expansion of the underlying database will improve the results in future versions of Viabundus.

Additional layers and information

63 For wayfinding in the Middle Ages, see Ruth Evans, „Getting there: wayfinding in the Middle Ages“, in Valerie Allen; Ruth Evans (eds.), *Roadworks: Medieval Britain, medieval roads* (Manchester 2016), 127-156.

64 See for example an analysis of sailing times on the Weser river in the 16th century, based on the Rinteln toll registers, in Heinrich Rüthing, „Beobachtungen zur Weserschiffahrt im 16. Jahrhundert“, in Jutta Bachmann; Helmut Hartmann (eds.), *Schiffahrt Handel Häfen. Beiträge zur Geschichte der Schiffahrt auf Weser und Mittellandkanal* (Minden 1987), 87.

Town outlines (16th century)

This layer shows the extent of the built area of towns in the 16th century, the period in which the oldest reliable drawn views and maps of towns are available for most towns. The town outline often follows the 16th-century fortifications or town walls, and is intended to provide the user a rough idea about the extent of the town area, for a better understanding of the location of the roads and the relation of the town with the surrounding landscape, which has often radically changed in modern times. For practical reasons, the town outlines are limited to the 16th century. The layer therefore does not give information about the historical development of the town area, nor about towns that were founded later. Neither has it been attempted to create outlines of all towns on the map or to reconstruct the street network within the towns. These features might be added in a future version of Viabundus.

For the settlements in the present-day Netherlands, the town contours have been mapped by the Dutch Cultural Heritage Agency (RCE) for the digital *Kaart van de verstedelijking* (Map of Urbanisation).[65] These contours are based on maps of Jacob van Deventer, made in the 16th century, probably somewhere between 1545 and 1575.[66] For the rest of the Viabundus map, the outlines of the towns have been drawn following a similar approach: for many towns in modern Belgium and the German border region with the Netherlands, town maps have also been drawn by Jacob van Deventer, which were not digitised by the RCE. For other regions, 16th-century town maps are available in other repertories, such as the town atlas *Civitates Orbis Terrarum* by Braun and Hogenberg (1572-1618), who have based their work on Jacob van Deventer for most of the towns in the lowlands, but included many larger towns in the rest of Europe as well. Moreover, the town views by Matthias Merian from the mid-17th century have been valuable, although it has been attempted to remove the 17th-century additions such as fortifications to reconstruct the 16th-century outline. If contemporary town plans were not available, the outlines were digitised according to reconstructed town plans in secondary literature, which is cited in the references of the corresponding node. Moreover, for many towns it is possible to reconstruct the extent of the medieval town walls based on still-existing parts of the walls or street names referring to defensive walls, ramparts or ditches (e.g. Mauerstraße, am Wall, Stadsgracht, etc.). For the towns in Westfalia, most of the town outlines are based on the reconstructions of historical building structure of the Westfalian towns in the *Westfälischer Städteatlas*, published in 11 volumes since 1975.[67]

Modern background map (OSM)

Viabundus offers three options for including a background map for the pre-modern streets and waterways. The default option is the open-source OpenStreetMap (OSM), that presents the current situation for reasons of comparison between the historical routes and the modern situation. Because of modern changes in the landscape, especially in heavily urbanized or industrialized areas, the current map in some regions presents a distorted context that does not help the understanding of the historical course of roads. For this reason, a palaeographical background map has been created that approximates the historical landscape around 1500 (see below). In addition, it is also possible to display a blank background.

65 https://www.landschapinnederland.nl/verstedelijkingskaart (consulted 12 August 2020).

66 Kosian; Van Lanen; Weerts, *Een nieuwe kaart van Nederland*; Reinoud Rutte en Bram Vannieuwenhuyze, *Stedenatlas Jacob van Deventer. 226 stadsplattegronden uit 1545-1575 - schakels tussen heden en verleden* (Bussum, 2018), 38-41.

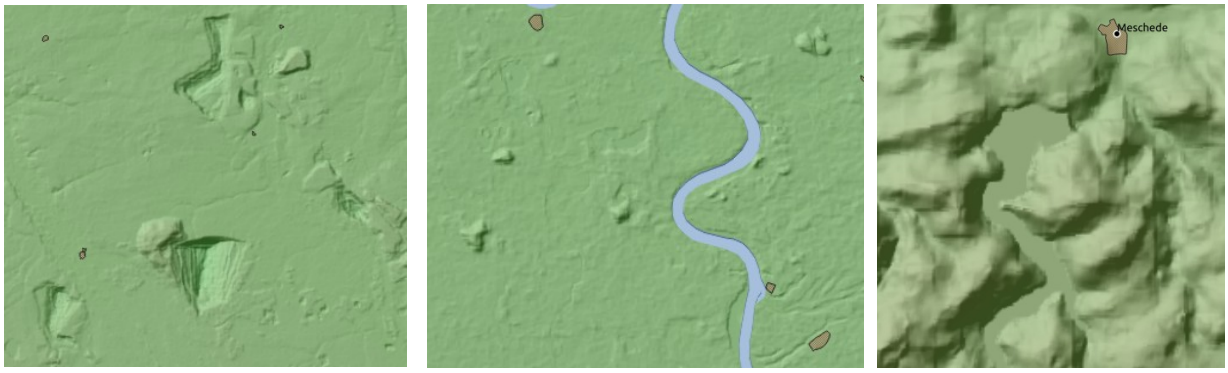
67 *Westfälischer Städteatlas*, 11 vols. ed. by Historische Kommission für Westfalen und das Institut für vergleichende Städtegeschichte IStG (Altenbeken, 1975-2010).

Paleaogeographical background map (1500)

The paleaogeographical background map consists of two elements that influence the course of roads and waterways: it shows the elevation of the terrain as well as the extent of larger bodies of water around 1500. Although it has been tried to be as accurate as possible, it should be kept in mind that the reconstruction of the pre-modern geography suffers from similar source problems as the reconstruction of roads (see above), and that the paleaogeographical background map was not intended to be the primary objective of Viabundus, but was rather included to put the pre-modern roads and waterways into context and to blend out the distortions when using a modern background map.

Elevation model

The elevation on the palaeographical background map is generated from the digital elevation model (DEM) of the European Copernicus satellite programme,[68] with the underlying assumption that in hilly and mountainous areas, where the elevation has the highest influence on the course of pre-modern roads, the elevation has undergone no significant natural changes during the last centuries. Nevertheless, modern activity has left its traces in the elevation of the landscape as well. Most of these modern disturbances are relatively small and visible mostly on high resolution DEMs, such as embankments of canals and highways. The 25m resolution used by the Copernicus DEM blends out most of those while maintaining a good level of detail. However, some artefacts of modern activity remain, such as large-scale mining activities and reservoirs in dammed valleys (see examples below). As these large-scale disturbances remain limited to a few instances and only cross pre-modern routes on a small number of occasions, we have not tried to eliminate them from the elevation model. Similarly, dunes in the coastal lowland areas have naturally wandered through the centuries, causing misalignments of the dunes and the historical coastline (see below) in some areas, such as the Wadden islands, but these areas only play a marginal role in the long-distance road system.



Lignite surface mines between Aachen and Cologne; Spoil tips from waste material from mining activity and traces of modern harbour structures in the Ruhr area near Duisburg; Dammed valley reservoir in the Sauerland region near Meschede.

68 Version 1.1. See https://land.copernicus.eu/imagery-in-situ/eu-dem/eu-dem-v1.1 (consulted 19 January 2021).

Water surfaces

In lowland areas, the course of routes was affected mostly through the existence of larger bodies of water (seas, lakes and large rivers) and wetlands such as marshes and bogs. While it has been impossible to include all wetlands in the period under consideration, we have included the coastlines of the North and Baltic Sea as well as the larger lakes and rivers for the year 1500. The basis for the water surfaces has been provided by the palaeogeographical map of the Netherlands in 1500 from the Rijksdienst voor Cultureel Erfgoed (RCE).[69] Some parts have been corrected slightly, such as the course of the Waal and Nederrijn rivers between Nijmegen and Emmerich[70] and the Maas river around Roermond.[71]

In a next step, the bodies of water were extended to include the remaining part of the region covered in Viabundus, with a special focus on the North Sea coast of Belgium, Germany and Denmark, the region that has undergone the most significant changes in coastline during the last five centuries. For the German North Sea, the coastline around 1500 has been reconstructed based on the publications of Hans Homeier for East Frisia and the Jadebusen region[72] and Dirk Meier for the North Sea coast of Schleswig-Holstein.[73]

For Denmark, the coastline has been drawn according to the map of Denmark of the Danish royal society for sciences (Kongelige Danske Videnskabernes Selskab) from 1762-1820. It includes most of the inland bodies of water that have since been drained. This represents the medieval situation fairly well, except in the Wadden Sea area of southwestern Jutland and the entrance of the Ringkøbing fjord. There the coastline has been corrected with the help of the *Historische Karte von den nordfriesischen Inseln Nordstrand, Pellworm, Amrum, Föhr, Sylt etc.* by Franz Geerz (Berlin, 1888), as well as various 17th-century sea maps. Moreover, the coastline has been corrected at the harbour of Copenhagen to represent the situation around 1500.

Contrary to the North Sea coast, the Baltic Sea coastline has seen much less drastic changes over the last five centuries, predominantly because of the lesser influence of tidal changes. This means that we can assume that the modern coastline represents the pre-modern situation in this region fairly well, with the exception of the coastal regions surrounding harbour cities. For this reason, the modern coastline has been taken from OpenStreetMap[74] (OSM) data, from which human-made modern harbour structures have been removed. The latter has been done based on the maps of Prussia from 1877 and the Russian empire from 1872, which have been included in the map “Europe in the XIX. century” on mapire.eu. For the German regions of Schleswig-Holstein and Mecklenburg-Vorpommern, the older sources used for the reconstruction of the roads were used as well (see above).

For the courses of rivers and lakes, a similar approach was taken: these have been drawn according to 18th-century maps, with incidental corrections for the time around 1500. The Schelde

69 P. Vos, M. Van der Meulen, H. Weerts and J. Bazelmans, *Atlas of the Holocene Netherlands, landscape and habitation since the last ice age* (Amsterdam 2020), online at https://www.cultureelerfgoed.nl/onderwerpen/bronnen-en-kaarten/overzicht/paleografische-kaarten

70 Based on Willem Overmars, *Een Waal Verhaal. Historisch-morfologische Atlas van de Rhein en de Waal. 1500-1700 Emmerich-Nijmegen* (PhD thesis, Vrije Universiteit Amsterdam, 2020).

71 Based on a map of the region around Roermond by Jacob van Deventer, ca. 1550 (Rutte and Vannieuwenhuyze, *Stedenatlas Jacob van Deventer*, p. 18 Fig. 10).

72 Hans Homeier, *Der Gestaltwandel der ostfriesischen Küste im Laufe der Jahrhunderte: ein Jahrtausend ostfriesischer Deichgeschichte*, Ostfriesland im Schutze des Deiches: Beiträge zur Kultur- und Wirtschaftsgeschichte des ostfriesische Küstenlandes, Bd. 2 (Krummhörn, 1969); idem, *Niedersächsische Küste: historische Karte*, 10 vols. (Norderney, 1961-1983)

73 Dirk Meier, Hans-Joachim Kühn and Guus J. Borger, *Der Küstenatlas: das schleswig-holsteinische Wattenmeer in Vergangenheit und Gegenwart* (Heide, 2013).

74 www.openstreetmap.org.

river in Flanders was based on the Ferraris maps of the Austrian Netherlands (1771-1778); the Rhine on the topographical map of the Rhinelands by Jean Joseph Tranchot (1801-1814) with corrections for the regions around the towns Neuss, Wesel and Duisburg[75]; the Weser and Elbe rivers as well as the lakes in Lower Saxony, Schleswig-Holstein and Mecklenburg-Vorpommern on the maps mentioned in the section about the reconstruction of roads in those regions. For the Polish regions of Greater and Lesser Poland and Masovia, the shapefiles of bodies of water from the online map of Polish lands of the Crown in the 16th century[76] of the Tadeusz Manteuffel Institute of History of the Polish Academy of Sciences has been used, which has been created with similar methods as described above. For other regions, natural lakes have been copied from OSM data.

Credits

Viabundus was created by the following persons:

- Bart Holterman: design, programming, research and mapping Lower Saxony, Holstein and other regions
- Maria Carina Dengg: research and mapping Thuringia, Saxony-Anhalt
- Maartje A.B.: research the Netherlands
- Kasper H. Andersen: research Denmark
- Friederike Kaplan: general GIS mapping
- Alexina Ludorff: database editing, mapping Schleswig, Pomerania, Estonia, Latvia
- Vivien Möller: database editing, mapping German coastlines
- Leendert van Prooije: research and database editing the Netherlands
- Afra de Mars: database editing, mapping the Netherlands
- Bart Ibelings: research and database editing the Netherlands
- Nathalie Rudolph: database editing
- Friederike Holst: database editing
- Annemarie de Vreese: database editing
- Peter Jensen: mapping Denmark
- Simon Harritz: database editing Denmark
- Caspar Skaaning Andersen: mapping Denmark
- Emma Klos: georeferencing Denmark

Project coordination and advisory board:

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- Stephan Freund
- Pierre Fütterer

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75 Jutta Prieur (ed.), *Geschichte der Stadt Wesel, Band 1*, (Düsseldorf, 1991); Joseph Milz and Hans-Georg Kraume, „Duisburgs Entwicklung als Handels-, Hanse- und Hafenstadt“, in *Leinen los! 275 Jahre Rhein-Ruhr-Hafen Duisburg, 13. - 22. September 1991. Duisburg und der Rhein: Begleitband und Katalog zur Ausstellung des Museums der Deutschen Binnenschiffahrt Duisburg-Ruhrort im Kultur- und Stadthistorischen Museum Duisburg, 15. September 1991 bis 12. Januar 1992* (Duisburg, 1991): 47-49; Jürgen Huck, *Neuss, der Fernhandel und die Hanse, Teil 1: Neuss bis zum Ende der Hansezeit* (Neuss, 1984), 147-148.

76 *Ziemie polskie Korony w XVI w. Przestrzenna baza danych*: http://atlasfontium.pl/index.php?article=korona&language=en (consulted 18 January 2021).

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- Rowin van Lanen
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