Simulation of historical Transport – A theoretical approximation

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This contribution will present basic considerations on use of computer-based simulation of historical transport systems. Simulation here is understood as a reproducible experiment, formulated in the scientific paradigm to emulate a process or state. Objective is to model, test and use complex systems to gain a better understanding of processes and the impact of individual factors, as well as realistic predictions or strong limitations of possible outcomes according to natural sciences. (Scheuermann, 2019/2020) The results constitute a field of possibilities, in which futures will happen. For the application to history, this means that simulations (in difference to other historical sources) do not tell or reconstruct exactly what happened, but narrow down the space in which history took place (Scheuermann 2020). This definition already results in central challenges for the use in historical research. On the one hand, the topic must be reproducible, which does not always apply to human action, and on the other hand, systems must be determined that completely cover a topic area. Transportation is a good application example for this, since here, in the sense of logistics, work processes can be determined and algorithmically mapped. The input parameters such as the exact course and the condition of the traffic routes, the human and animal actors, the transport circumstances, such as weather etc. appear to be the bigger issue. In the case of roads and bodies of water as well as the infrastructure, they must be determined by classical archaeological work. The more exact the routes are the more reliable are the results of the simulation. The same applies to the performance factors of the means of transport, which have to be determined in real-world experiments, which also serve as benchmark data for validating the simulation.

The following workflow (Figure 1)) describes the general course of the development of a simulation. The first step is the design and the implementation of a model of a delimited part of the reality, in which the scope, input data and necessary algorithms are defined. After the technical implementation (collection of the data and the development of the application) the ‘simulation calculations’ (or simulation experiments) are carried out. In a further step, the resulting data have to be validated against separate real-world experiments or other simulation systems. This step is crucial for the quality of the simulation system. If differences between the results of the simulation and benchmark data occur, the simulation system has to be refined until the results are in sufficient accordance

In general, simulations can be divided in time-invariant (static) and dynamic types, in which temporally preceding results influence the following ones. While static simulations deal with ‘systems at rest’ or states of a system, dynamic simulations ‘include assumptions about the time-evolution of the system’ and deal with processes (Hartmann 2010, p. 82).[1] For the calculation of transport times

[1] A typical type of historical transport and travel simulation is the Least Cost Path Analysis. Every place in this approach has a ‘affordance’, which represents a) movement potential (the quality of the place to be used as a traffic route) and b) the quality of being reached (accessibility). Affordance depends on the energy expenditure of travelers and is calculated by cost algorithms – mainly depending on the slope of the place. A matrix of affordance in space can be used to calculate a route of least effort between two places – a route of least cost, which is interpreted as the most likely historically used route one. This approach has been developed in context of pre-historic site catchment analysis and targets on longue durée transregional processes and structures. However, it does not appear to be very suitable for the reconstruction of historically documented traffic routes and, in addition, for calculating transport times, even though there are several approaches to do so.

dynamic simulations, that include factors like constantly changing weather conditions and the fatigue that grows throughout the travel, are needed.

A dynamic simulation is implemented in then STRADA-system, which is developed in an ERC-consolidator grant project since 2021.[2] It follows a multi-agent-based approach, in which numerous individual actors with a common set of rules move on the archaeologically reconstructed traffic routes (rivers and roads). The largest time unit of the simulation is days. At the beginning of a day, agents start at short intervals with all the means of transport available at the respective location. Their speed is depending on the mode of transport, the load, the slope, the temporal and spatial local weather conditions and the respective fatigue of the individual actor.[3] The smallest room units were defined so that the required time can be determined based on the speed. In the course of the distance covered, the fatigue increases until a mark is exceeded at which the respective actor must pause. If an agent arrives at a place where changing the mode of transport is possible, it will be cloned, i.e. several versions continue with different modes of transport. The end of a day tour marks the time of sunset. The whole simulation ends, when all agents have reached the destination. The result is a time distribution of the arrival times of the agents, which can be interpreted as a probability distribution.

The architecture of the system is strictly modular, so that it can easily be adapted for other times and spaces as well as for different means of transport. All modules can also be freely expanded and refined. The aim is to find further projects that develop their own scenarios based on STRADA and thus ensure a sustainable improvement of the system.

Finally, it is necessary to discuss what the simulation results exactly represent. Many so-called ‘soft’ factors, which often had a major influence on the course of historical transport, can no longer be reconstructed without the appropriate written sources. This includes the personal preferences of the actors (e.g. the drivers of the animals) regarding the route or overnight stays. Also not included are religious factors such as travel bans on holidays or rituals that required a certain amount of time, or even the daily condition of the actors. Therefore, approximately realistic statements about the durations of an individual historical transports are not calculable by computer-based simulations, because they do not (or only to a certain extent) depend parameters that can be formulated scientifically. However, statistical statements about average transport times and minimum durations can be made and both values certainly represent a basis for the planning of historical transports. The aim of a simulation of historical transport is therefore to reconstruct the horizon of experience of historical logisticians (dealers, responsible positions in the military and administration) as well as to determine the value of individual parameters in the system. Of particular interest, here is the variance of arrivals and the influence of the local weather on them. The central question that arises is whether and how well transport times were predictable or even calculable for the historical actors, and whether they could serve as a basis for economic action. Consequently, it needs to be asked to whether extent this predictability changed in the context of historical climate change and what effect this had on the existence of an overarching economy such as the Roman Empire.

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[3] As already mentioned, the performance factors influencing the speed are determined in an experimental archeological test series.

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