Oliver Nakoinz, Zentralität. Theorie, Methoden und Fallbeispiele zur Analyse zentraler Orte. Berlin Studies of the Ancient World Band 56. Edition Topoi, Berlin 2019. € 33.90. ISBN 978-3-9819685-4-5. doi: https://doi.org/10.17171/3-56. 238 pages.

To review Oliver Nakoinz' 2019 book *Zentralität* (engl. *Centrality*) for *Germania* was a challenging task – mostly because O. Nakoinz' theoretical and methodical approaches are based on a long-standing discourse in the field of quantitative and qualitative archaeology. It soon became clear that this book not only includes a discussion about Central Place Theory, but is much more than that: besides its functionalist-like segmentation of theoretical and methodological details about the origin and subsequent development of Christaller's work from the early 1930's, this book further provides a tool to understand the author's own scientific development, which has significantly influenced digital and quantitative archaeological research for over two decades now. What is more important, this volume offers the reader a broad spectrum of theoretical (but not only) approaches to model, visualise, and interpret distributions of archaeological material. It is not surprising that Nakoinz, who completed his PhD and his habilitation at the Christian-Albrechts-University at Kiel, spiced up his thoroughly theoretical book, written during a Senior Fellowship at the Excellence Cluster Topoi in Berlin, with a significant number of case studies and applications, which help the reader to understand the applicability of these methods to elucidate site distribution patterns and to enable the interpretation of large (spatial) datasets. The book is available online (doi: https://doi.org/10.17171/3-56) and as printed version and was edited by the *e-topoi* edition of the *Berlin Studies of the Ancient World* (Vol. 56) in 2019.

A broad theoretical and methodical part is divided into a short introduction, followed by a more detailed presentation of the evolution and reception of Christaller's work and a summary of international as well as recent approaches to Central Place Theory. Nakoinz then introduces what he calls *Modifikation der Zentralitätstheorie* (chapter 3, Modification of the theory of centrality, p. 51). This is the moment where the book begins to develop its own characteristic appearance – mostly because the theoretical discourse increases in complexity and at the same time starts to connect with mathematical formulas, pointing towards the actual modelling approach of the author. It is also the part, which basically defines the terminological environment of centrality, albeit in an extraordinarily broad way. The strength of Nakoinz' work here is the very comprehensive discussion of the manifold variables and parameters underlying centrality, intensity, and interaction, which testifies that this book is the result of many years of continuous work in archaeological method and theory. As a result, the definitions can be considered dense – or rather condensed – simplifications of the broader theoretical discourse, which makes it sometimes difficult to follow the author's thoughts (particularly if the reader is not familiar with the theory behind quantitative models). Nakoinz does not attempt to provide an economic theory of centrality in the very sense of Christaller, but rather to emphasise a more generalised approach. In this context, his definitions are important steps towards a meaningful explanation of centrality. The first statement defines *Zentralitätsintensität* (intensity of centrality), which is understood as "relative concentration of interaction" (p. 53). With this basic definition, Nakoinz emphasises the relative and gradual nature of intensity of centrality compared to population density and the structure of the surrounding complementary region. Shortly afterwards, he defines *Interaktion* (interaction) as a "mutual action of at least two interaction partners" (p. 57), which includes information exchange (communication), exchange of goods, mutual activities, physical manipulations, and their various subtypes. It now becomes clear that interaction represents a major hub in the concept of centrality, and the author acknowledges this by including a broad discussion about interaction systems and structures, which eventually leads to the construction of interaction models (p. 61) and interaction organisation (p. 62). There, distance-based "gravity models" and the concept of "entropy" are introduced, which represent potential

tools to evaluate distance-related meaning of a particular location or to identify those interactions that enable optimised interaction within the entire system. In such a system, transportation *(Transportkost)* and route costs *(Wegekost)* increase in significance in the moment of increased frequency of the interaction intensity. That leads to attempts towards minimization / optimisation of these costs in the moment or over a temporal interval of mutual interaction. Using collective action theory to build synergies, these considerations trigger the development of main route axis and infrastructure or high transport capacities. However, as Nakoinz points out correctly, environmental prerequisites play a decisive role as factors influencing the location of a settlement itself and as the major determinant of local accessibility and terrain permeability (pp. 64; 98).

It is not very surprising that these well-known variables show up quite frequently in the book; however, I would like to highlight one particular section in which Nakoinz compares demographic dispersal, the concentration of interaction, and potential environmental suitability for human occupation (chapter 4.7, Strategy of analysis, p. 155). In this section, he states that centrality is not accomplished if a population is maximally dispersed according to the immediate environmental parameters. If the empirically observed distribution is significantly different from the theoretically ideal distribution, we can conclude that a particular interaction was necessary and that centrality is achieved in the core density area. This furthermore takes into account the organisational structure of the place itself in relation to the surrounding places and settlements, which enables centrality (p. 160).

From this point of view, it is easier to understand that centralisation processes can be observed in settlement systems, and that these systems follow optimised parameters to maintain persistence (p. 87). The reconstruction of supraregional settlement systems, however, requires the knowledge of each single hub in the system – a rather optimistic assumption, considering the scattered and incomplete nature of the archaeological record (p. 97). To overcome this limitation, Nakoinz refers to the implementation of *models* to compare the observed archaeological distribution to a theoretical distribution. A *model* is an *icon*, which represents relevant characteristics of an object in terms of a particular parameter (p. 82). He aims at constructing a most simplified (comprehensive and efficient) theoretical and deductive model, which most accurately predicts an empirical and inductive model (pp. 83–85). The general differentiation between inductive and deductive models is also an important feature to understand two major aspects of site distribution analyses (p. 99): in principle, the inductive approach tries to build up a model from the evidence, while a deductive approach builds a model from a theory and then tries to see if the evidence fits. In reality, theory always lies behind the inductive process of building a model from evidence, and evidence always lies behind the theory that you try to fit the model to.

Apparently, empirical data (nodes, edges, structures) is basically what makes archaeology quantifiable. Nakoinz introduces *centrality indices* to determine weighted and / or directed "networks", based on "nodes" (or vertices, *Knoten*) and "edges" *(Kanten)*, which are the two units that construct the network (graph) (p. 75). In such a network, the centrality of each node is a measure of its relationships to all the other nodes in the network (p. 139). The above-mentioned differentiation into nodes (in this case: points) and edges (the connection between two points) forms the respective "interaction structure", which can help to reconstruct interaction spheres and so-called "territories" (pp. 97–98). In an inductive model, this structure is built by the environmental prerequisites and the individual and group affordances of the local population. From the site distribution and the interaction edges, the prevailing physical characteristics can be derived, which form the respective territorial composition of one region, the central places dispersed therein, and their complementary areas. Of course, this is a reductionist approach (just like the model itself), and one can argue to what extent human-made landscapes are the construct of merely physical interaction processes or

whether they are conceptualisations of both environmental factors and individual affordances in the moment of mutual interaction. Broadly speaking, landscape development (and thus also settlement patterning) is the result of the mental perception of spatio-temporal environmental variability and not simply a manifestation of topography, hydrologic system, and climate determinants. Modelling such cognitive variability in the development of landscapes and ecosystems, however, can be considered a major challenge – particularly in archaeological research, due to the limitations described above.

Nakoinz further offers a broad variety of methods to analyse, visualise, and interpret site distribution, mostly based on previous work and well-established approaches of point pattern analysis (chapter 4.3.4, Distribution, and 4.3.5, Density, pp. 103–111). His major focus lies on the analyses of interaction node concentrations, which is mirrored in the exemplary performance of sequential nearest-neighbour analysis, CSR-test (Complete Spatial Randomness), KDE (Kernel Density Estimation), and Monte-Carlo-Simulations with a specific emphasis on moving-window operations and Voronoi-densities. With these technically sound operations, the spatial properties of a point pattern (nodes) can be analysed. The methods (such as the G-Function in a Monte-Carlo-Simulation) evaluate whether the observed point pattern is different from a theoretical distribution (tested many times against a random comparison dataset) or if they are drawn from the same (random) sample. This allows for the detection of clustered behaviour, regular dispersal, or random point distribution. Eventually, this results in a density map of the point pattern, from which density anomalies (p. 110), interaction node densities (p. 111), and local density maximum values (p. 114) can be derived. From these analyses, the author suggests centrality of specific places. In a next step, he also includes distance-based measures to evaluate whether the degree of overlap of the single interaction regions (complementary region, *Ergänzungsgebiet*) is high or low. In the very sense of Christaller's approach, an ideally tessellated distribution of complementary regions equals non-overlapping interaction regions, which Nakoinz defines as territories (p. 119). Such territories can be calculated using spatial analysis technique implemented in QGIS and GRASS GIS, which produce a two-dimensional distance-based Voronoi-diagram (pp. 119–120). Nakoinz further refers to weighted Voronoi-diagrams, which integrate specific parameters pre-processed in a so-called cost-surface (e. g., terrain roughness, accessibility, hydrologic system) and enable the calculation to leave the two-dimensional level in favour of multivariate statistics.

The book then starts to dive deeper into network analysis and the construction of "ideal" and the reconstruction of "real" networks (chapter 4.5, Methods to analyse interaction networks, p. 132), and Nakoinz lists important aspects of how to set up optimal pathways, including transportation and route costs. The ultimate goal is to achieve a combination of a minimal "spanning tree" *(Spannbaum)* and the entire graph. This means a weighted hierarchical differentiation into directed long-distance transportation between the central places and an all-channel-network between the lower local classes and their nearest central place (pp. 133–134). As mentioned earlier, the author uses centrality indices to determine whether there is interaction between two nodes (pp. 140–142) (see also L. C. Freeman, Centrality in social networks conceptual clarification. Social Networks 1,3, 1978, 215–239. doi: https://doi.org/10.1016/0378-8733(78)90021-7). Among other indices, Degree Centrality (tZI_1, t=theoretical) measures the number of neighbours of each node in particular distances and/or relations around the node. The index Closeness Centrality (tZI_2) can be used to identify the nodes, which are capable of spreading information through the graph in a most cost-effective way. It is the inverse-distance of the node to all other nodes in the graph, which produces a short-distance ranking and enables one to measure interdependency of nodes. The so-called Betweenness (tZI_3) assesses the degree to which a node lies on the shortest path between two other nodes (see also T. Opsahl / F. Agneessens / J. Skvoretz, Node centrality in weighted networks: Generalizing degree and shortest paths. Social Networks 32,3, 2010, 245–251. doi: https://doi.

org/10.1016/j.socnet.2010.03.006). A high degree of Betweenness enables a central place to control information-flow in a network. This selection of centrality indices, however, does not include the degree of interaction between two places and thus represents only a potential centrality (p. 142). For this reason, Nakoinz redefines the centrality indices to weighted centrality indices that consider weighted edges within the graph (pp. 142–145). For example, the Weighted Degree Centrality (rZI_1, *r=real*) represents the sum of all edge-weights in relation to all neighbours. It is the sum of the weights assigned to the direct connections of the node and represents the node strength (L. Candeloro / L. Savini / A. Conte, A new weighted degree centrality measure: The application in an animal disease epidemic. PloS One 11,11, 2016, e0165781. doi: https://doi.org/10.1371/journal.pone.0165781). (rZI_1) can further be split into incoming (rZI_1e) and outgoing (rZI_1a) Weighted Degree Centrality, which determine the sum of the edge-weighted interactions incoming from and all outgoing interactions towards all neighbours. Similarly, the Weighted Closeness Centrality (rZI_2) measures the sum of the minimum edge weight of the edges in the shortest paths divided by the path length for the other points – and can be distinguished accordingly. Nakoinz further differentiates the Weighted Betweenness (rZI_3) into (rZI_{31}), which is the sum of the minimum edge weights of the shortest paths between all points on which the observed point is situated, and (rZI_{32}), which is the sum of the minimum edge weights of all edge-disjoint paths between all points on which the considered point is located.

None of these indices is a universal indicator of centrality, but they allow one to identify different types of centrality in the nodes of a network (p. 145). The comparison of the different aspects of centrality – interaction intensity (I), interaction outreach (R), hierarchical level (H), interaction control (K) – can then be described as a vector of total centrality (I,R,H,K) (p. 146). Based on the interaction intensity of a node, (I) is defined as the sum of all interactions, and the integration of distance relations enables one to draw conclusions about (R). (H) is derived from the comparison of neighbouring indices, and (K) is basically represented by Betweenness and the ability to allow or prevent contact between potential interaction partners. Depending on the character of the network (free, bound, weighted, directed, hierarchical etc.), the Closeness parameter can be used to determine the degree of site location intervention and optimisation.

This section (chapter 4.5.3, Network Analyses, p. 138) can be considered a major result of the volume. Nakoinz introduces a great many potential algorithms to calculate and interpret total centrality of different kind of networks (pp. 148–153), which can be used in manifold ways. The very detailed summary of centrality theory, which accompanies the discussion during the first 150 pages of the book, culminates in these seemingly simple considerations about potential centrality of places within certain networks. However, as Nakoinz points out on page 146, the theoretical approaches to centrality theory are often lacking. Furthermore, stand-alone manifestations of theoretically derived definitions are neither useful nor reproducible for a broad readership in archaeological research.

This book provides a highly suitable manual for understanding centrality and network theory and further enables the reader to reproduce the models based on their own archaeological point data. Although the book itself does not appear very attractive to a merely superficial reader who wants to gloss over theoretical details and methodical approaches of quantitative modelling and certainly meets with some editorial inadequacies related to the final stage of the Excellence Cluster Topoi, it can be considered a major advance in computational archaeology and summarises quite sufficiently the scientific approaches of Oliver Nakoinz.

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