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Explaining the maritime freight charges in Diocletian's Price Edict

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Abstract: Geospatial modeling enables us to relate the maritime freight charges imposed by the tetrarchic price controls of 301 CE to simulated sailing time. This exercise demonstrates that price variation is to a large extent a function of variation in sailing time and suggests that the published rates are more realistic than previously assumed.

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In an article published in 2007, Pascal Arnaud explored the price ceilings for maritime transport stipulated in the famous tetrarchic price edict of 301 CE.[1] In this document, maximum allowable freight charges for specific sea routes are expressed in *denarii* (*communes*) per *modius kastrensis*, the edict's favored capacity unit that equaled 1.5 *modii italici* or about 12.9 liters. In contrast to unsuccessful earlier attempts to relate the attested prices to nautical distance, Arnaud argued that expenses reflected sailing time. Extrapolating from a handful of attested durations of sea voyages that match particular routes mentioned in the edict, he hypothesized that the number of *denarii* in the prices was derived from the number of days of travel, at a conversion rate of 1 *denarius* per day. In his view, the compilers of the text had used this schematic formula to create standardized price ceilings.[2]

If correct, Arnaud's intuition offers a novel way to make sense of the otherwise decontextualized freight rates reported in the edict. Earlier scholars had failed to establish a meaningful relationship between the attested prices and putative distances.[3] In maritime transport, however, sailing time rather than distance is the critical variable. Arnaud's approach is consequently more promising a priori grounds. Even so, he was unable to test his hypothesis in a more systematic way due to the fact no Roman sailing times are documented for most of the routes specified in the edict. This is due to the objective of the text: while Hellenistic and Roman geographical sources report normative sailing times for numerous sea routes in the Mediterranean and the Black Sea,[4] few of them were of use to the compilers of the edict as they sought to impose price ceilings on connections between the main political centers of the Later Roman Empire, such as Nicomedia, Alexandria, Antioch, Rome and Carthage, as well as a series of coastal provincial centers, which are either named (such as Aquileia, Ephesus or Thessalonica) or have to be inferred from provincial designations (such as Tarraco or Carthago Nova for Spania or Gades for Baetica). Moreover, no fewer than four of the five cases in which Arnaud observed matches between prices in *denarii* given in the edict and days of travel documented elsewhere wholly or partly depend on the use of non-geographical sources that do actually not purport to provide normative information about sailing time. For these reasons, his entire reconstruction rests on extremely shaky empirical foundations.

In the absence of evidence capable of directly corroborating his proposed conversion formula, Arnaud had to fall back on relating documented normative sailing times to discrete elements of the often more elongated routes specified in the edict. This procedure suggested to him the presence in the edict of multiple schematic calculations that were intermingled with empirical observations, prompting his rather bleak conclusion that "[t]he Edict thus seems to be a strange mixture of empirical data and of bureaucratic simplifications and (mis-)calculations, relying above all upon an abstruse, arithmetical view of ancient seafaring."[5]

In the following, I show that Arnaud's intuition that the edict's price ceilings are a direct function of sailing time and that the number of *denarii* corresponds to the number of sailing days is supported by a new simulation of maritime transport in the Roman period. This finding calls for a more optimistic assessment of the edict's reliability and internal consistency than the one proffered by Arnaud. For the first time, *ORBIS: The Stanford Geospatial Network Model of the Roman World* makes it possible to

[1] P. Arnaud, "Diocletian's Prices Edict: the prices of seaborne transport and the average duration of maritime travel," *JRA* 20 (2007), 321-336.
[2] Arnaud (n.1), 330-1.
[3] R. Duncan-Jones, *The economy of the Roman Empire* (Cambridge ^{2}1982), 367-8, and cf. also J. Rougé, *Recherches sur l'organisation du commerce maritime en Méditerranée sous l'empire romain* (Paris 1966), 98-9; K. Hopkins, "Models, ships and staples," in P. Garnsey and C. R. Whittaker (eds.), *Trade and famine in classical antiquity* (Cambridge 1983), 102-4; Arnaud (n.1), 329.
[4] Collected in great detail by P. Arnaud, "Les relations maritimes dans le Pont-Euxin d'après les données numériques des géographes anciens (pseudo-Skylax, Strabon, Pomponius Mela, Pline, Arrien, Anonyme de 500, Marcien d'Héraclée)," *REA* 94 (1992), 57-77; *Les routes de la navigation antique: itinéraires en Méditerranée* (Paris 2005).
[5] Arnaud (n.1), 334.

calculate average sailing times for a large number of routes across the Roman Empire.[6] Created at Stanford University by a team of IT experts led by Elijah Meeks under my direction and with inputs from Stanford graduate students, this interactive model reconstructs the duration (and price cost) of travel by simulating movement along well over a thousand road and river segments and sea lanes. Sea travel moves across a cost surface that simulates monthly wind conditions and takes account of strong currents and wave height.[7] The model allows calculation of average sailing times for a given route for each month of the year and for two types of sailing ships which differ slightly in terms of navigational capabilities. Employment of the (marginally) faster ship type generates outcomes which cumulatively precisely match cumulative sailing times for 65 Mediterranean sailing routes involving voyages of 24 hours or longer that are reported in Greco-Roman geographical sources. In the aggregate, the resultant simulations provide the closest approximation of Roman-period sailing performance currently available.

The edict lists 49 routes with identifiable sources and destinations (which are however often only defined as regions rather than as specific ports) for which maximum prices have survived in the epigraphic record.[8] Using ORBIS, I have simulated mean sailing times for each of 46 Mediterranean routes and two Black Sea routes for each of the seven months from April to October, which represent the main sailing season in the pre-modern Mediterranean.[9] In three cases, routes were simulated twice with different end points to account for the lack of clarity of the record, and the results averaged from both options; the differences are minimal and do not affect overall outcomes.[10]

The simulated trajectories of the routes are displayed in Figure 1. Table 1 lists the reported locations, inferred ports, reported prices, and mean simulated sailing time in days (averaged over the seven months in question). Sailing times are given net of the mean current constraints imposed by the model.[11]

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[6] W. Scheidel and E. Meeks, *ORBIS: The Stanford Geospatial Network Model of the Roman World* (May 2, 2012), http://orbis.stanford.edu. I take this opportunity to acknowledge the Stanford Digital Humanities Grant that made this project possible.

[7] See http://orbis.stanford.edu/#seatransport for a description of the underlying parameters.

[8] Conveniently tabulated by Arnaud (n.1), 336.

[9] One Black Sea route, from Byzantium to Tomis, has been omitted because of the difficulty of assessing the impact of the exceptionally strong southward currents in the Bosporus, which would have delayed travel into the Black Sea (see E. Taitbout de Marigny, *New sailing directions of the Dardanelles, Marmara Sea, Bosphorus, Black Sea, and the Sea of Azov* [London 1847] and esp. B. W. Labaree, "How the Greeks sailed into the Black Sea," *AJA* 26 [1957], 32), a constraint on sailing speed that is factored into the averages computed by *ORBIS*. For related problems regarding the Hellespont (Dardanelles), see below, n.14.

[10] These are three routes to "Spania", represented by both Tarraco and Carthago Nova.

[11] Where applicable, *ORBIS* adds travel time to trips through straits that produced strong currents. See above, n.9, and National Geospatial-Intelligence Agency, *Sailing directions (enroute): Eastern Mediterranean* (no place, 13th ed. 2011), 236; National Geospatial-Intelligence Agency, *Sailing directions (enroute): Western Mediterranean* (no place, 15th ed. 2011), 3. It does not seem appropriate to include these adjustments in the following simulations as we cannot readily expect the edict to have taken account of the underlying constraints: see below, n.14.

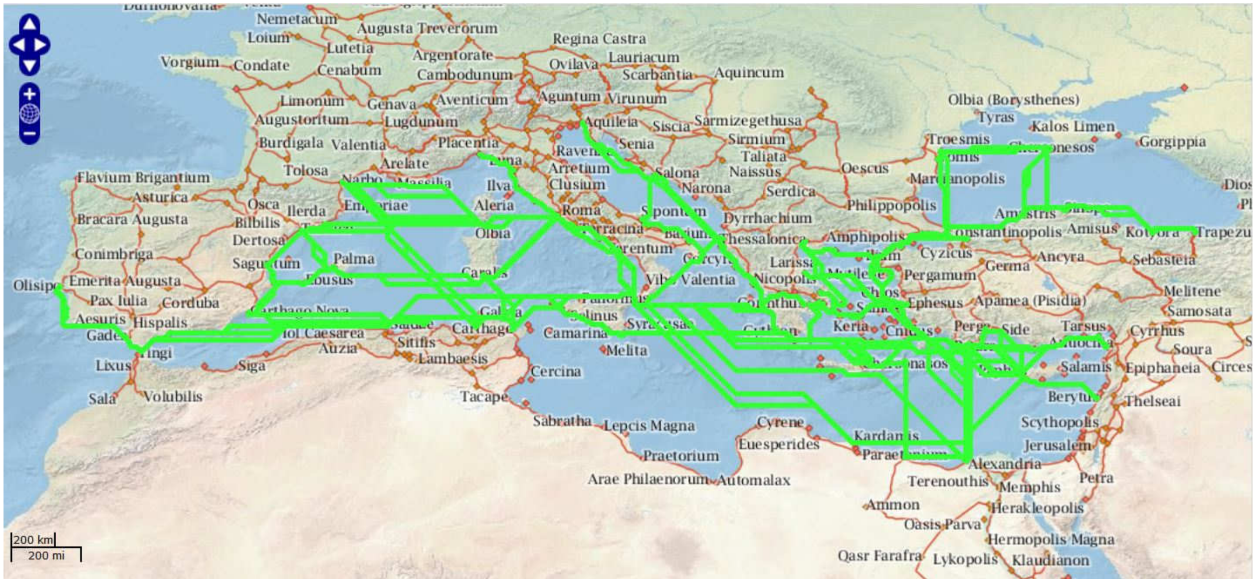

Fig. 1 Sea routes derived from the Price Edict

Table 1 Reported prices and simulated sailing times

Start point		End point		Price	Duration	Ratio
Attested	Inferred	Attested	Inferred	(*denarii*)	(days)	price/duration
Alexandria	-	Roma	Ostia/Portus	16	17.7	1.11
Alexandria	-	Nicomedia	-	12	12.6	1.05
Alexandria	-	Byzantium	-	12	12.2	1.02
Alexandria	-	Dalmatia	Salona	18	19.0	1.06
Alexandria	-	Aquileia	-	24	21.9	0.91
Alexandria	-	Africa	Carthago	10	17.4	1.74*
Alexandria	-	Sicilia	Messana	10	13.3	1.33
Alexandria	-	Ephesus	-	8	6.9	0.87
Alexandria	-	Thessalonice	-	12	11.0	0.92
Alexandria	-	Pamphylia	Side	6	5.3	0.88
Oriens	Seleukeia Pieria	Roma	Ostia/Portus	18	21.8	1.21
Oriens	Seleukeia Pieria	Salona	-	16	20.5	1.28
Oriens	Seleukeia Pieria	Aquileia	-	22	23.2	1.05
Oriens	Seleukeia Pieria	Africa	Carthago	16	20.4	1.28
Oriens	Seleukeia Pieria	Spania	Carthago Nova or Tarraco	20	27.7	1.39*
Oriens	Seleukeia Pieria	Baetica	Gades	22	32.2	1.46*
Oriens	Seleukeia Pieria	Lusitania	Olisipo	26	36.2	1.39*
Oriens	Seleukeia Pieria	Galliae	Narbo	24	27.7	1.15
Oriens	Seleukeia Pieria	Byzantium	-	12	13.5	1.13
Oriens	Seleukeia Pieria	Ephesus	-	10	8.1	0.81
Oriens	Seleukeia Pieria	Sicilia	Messana	16	17.3	1.08
Asia	Ephesus	Roma	Ostia/Portus	16	15.2	0.95
Asia	Ephesus	Africa	Carthago	8	13.9	1.74*

Asia	Ephesus	Dalmatia	Salona	18	13.9	0.77
Africa	Carthago	Salona	-	18	11.7	0.65*
Africa	Carthago	Sicilia	Messana	6	3.7	0.62*
Africa	Carthago	Spania	Carthago Nova or Tarraco	8	7.8	0.98
Africa	Carthago	Galliae	Narbo	4	7.3	1.83*
Africa	Carthago	Achaia	Corinthus	12	8.7	0.73
Africa	Carthago	Pamphylia	Side	14	14.2	1.01
Roma	Ostia/Portus	Sicilia	Messana	6	3.7	0.62*
Roma	Ostia/Portus	Thessalonice	-	18	17.1	0.95
Roma	Ostia/Portus	Achaia	Corinthus	14	8.7	0.62*
Roma	Ostia/Portus	Spania	Carthago Nova or Tarraco	10	8.8	0.88
Roma	Ostia/Portus	Galliae	Narbo	14	6.5	0.46*
Sicilia	Messana	Galliae	Narbo	8	10.9	1.36*
Nicomedia	-	Roma	Ostia/Portus	18	20.0	1.11
Nicomedia	-	Ephesus	-	6	4.3	0.72
Nicomedia	-	Thessalonice	-	8	5.4	0.68
Nicomedia	-	Achaia	Isthmia	8	7.5	0.94
Nicomedia	-	Salona	-	14	18.2	1.30
Nicomedia	-	Pamphylia	Side	8	7.9	0.99
Nicomedia	-	Phoenicia	Berytus	12	9.9	0.83
Nicomedia	-	Africa	Carthago	14	18.2	1.30
Amastris	-	Tomis	-	8	5.1	0.64*
Sinope	-	Tomis	-	8	6.1	0.76
Sicilia	Messana	Galliae	Narbo	8	10.9	1.36*
Byzantium	-	Roma	Ostia/Portus	18	19.4	1.08
Total				634	670.9	**1.06**

This survey shows that on average, 1 *denarius* would have paid for 1.06 days of sailing, an exceptionally close match. Considering that individual ORBIS simulations entail a margin of error of up to +/-30 percent, it is remarkable how closely many routes approximate Arnaud's proposed conversion rate of 1 *denarius* per day (Fig. 2). The correlation coefficient (*r*) for all 48 routes is 0.88, which means that 77 percent of variance in prices can be explained as a function of variance in sailing time.[12]

[12] Contrast the correlation between prices and distances of 0.72 (covering 52 percent of variance) estimated by Hopkins (n.3), 102-3.

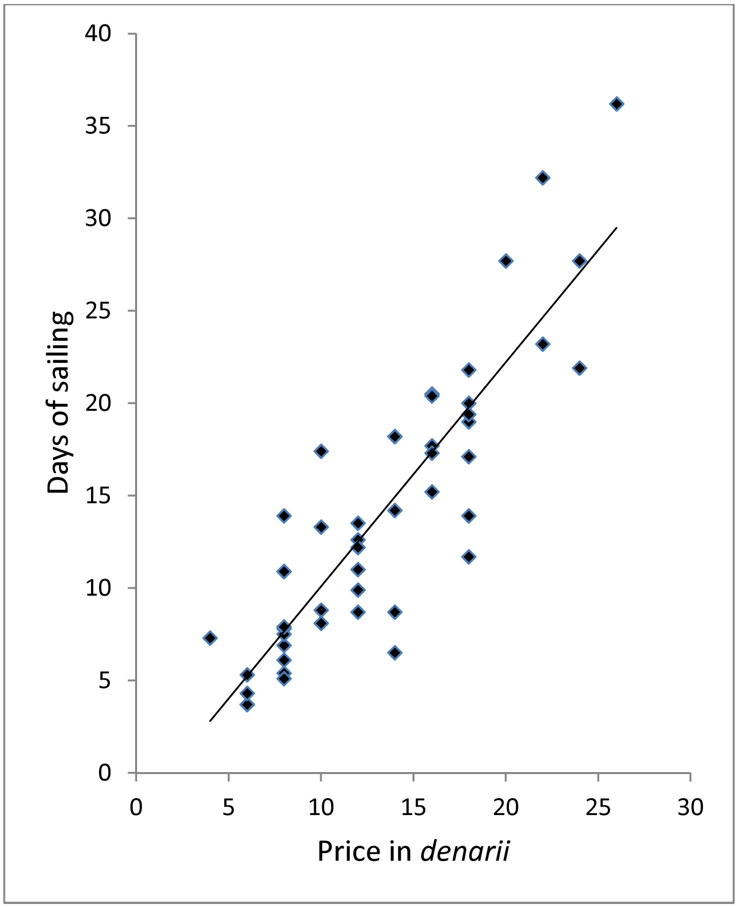

Fig. 2 Correlation between maximum prices and sailing time

14 of the 48 durations (marked with * in Table 1) deviate from expected durations by more than one-third, although most of them by little more than that. Looked at more closely, most of these apparent outliers do not pose major problems of interpretation. One of them refers to the Black Sea, where the model simulations are more schematic than in the Mediterranean and generally to be taken with a double dose of salt. The three ostensibly slower-than-expected connections between Syria and the Iberian peninsula are unlikely to represent genuine continuous routes: we should not put too much weight on deviations for such constructs. Ships sailing from Alexandria to Africa were slowed down by the strong northwesterly summer winds, a constraint that the compilators admittedly ought to have been familiar with. While the duration of the voyage from Carthage to Narbo is much longer than predicted for the Africa-Galliae route in the edict, selection of an alternative route from Cape Metagonium, a common reference point for open sea voyages in the geographical sources, to Provence would result in a much closer match of around 5 travel days for 4 *denarii*. While the implied 14 days of sea travel of from Rome to Provence are excessive for an open sea voyage, use of a coastal route would remove this problem: according to *ORBIS*, it could easily take 9 days of continuous summer sailing or 14 days with nightly stops to complete this trip in coastal waters.[13] The only genuine howler appears to be the implied travel time of 8 days from Asia to Africa, which is improbably short under any circumstances.

[13] Cf. J. H. Pryor, "The voyage of Rutilius Namatianus: from Rome to Gaul in 417 C.E.," *Mediterranean Historical Review* 4 (1989), 271-280. By contrast, Arnaud (n.1), 334 conjectures a detour via the Straits of Bonifacio.

I therefore submit that a few minor concessions to occasional bureaucratic inconsistency are sufficient to restore the edict's reputation to that of a necessarily rough but mostly sound compilation of price proxies for plausible sailing times. Most importantly, implied sailing times for what were arguably the most important and best-attested routes conform very closely to model simulations. The projected travel times from Nicomedia or Byzantium to Rome, from Alexandria and Antioch to Nicomedia or Byzantium, and from Rome to Carthage cumulatively deviate by only 8 percent from the predicted values, for a ratio of 1 *denarius* per 1.08 days.[14] As it would seem naïve to assume that the edict's compilators obtained their time/price conversion ratio by performing an expansive averaging exercise akin to the one undertaken in Table 1, we may speculate that this scheme was more parsimoniously constructed around a few key ratios derived from principal routes and then applied to other routes by assigning *denarius* values to known or computed sailing times. With only few glitches, this procedure led to adequate results. We may hope that this finding will encourage more general reconsideration of the value of the prices recorded in the edict.[15]

[14] Elimination of the impact of currents on mean sailing time affects (i.e., reduces) the simulated voyage durations to Nicomedia or Byzantium (see above, n.9). There is no good reason to assume that the edict's compilators sought to address this issue by building average delays into their maximum prices for northward trips through the Dardanelles or Bosporus: not only is the entire document highly schematic and apodictic, the sections on allowable charges for transport by land and river show no appreciation of varying contexts (such as river velocity, which would have affected the real-life cost of upriver shipping) or other contingencies. Disregard for complications such delays of chaotically varying length (as in the case of these straits) would have been the most straightforward *modus operandi*. Moreover, this conservative assumption yields the best fit between simulated sailing times and stipulated prices.

[15] The present confirmation of the Arnaud hypothesis does not tell us whether the price *levels* envisioned by the edict were realistic. Expressed in wheat equivalent, the riverine freight rates in the edict (XXXVA.33-5) seem compatible with several real-life freight rates from Roman Egypt (A. C. Johnson, *Roman Egypt to the reign of Diocletian: an economic survey of ancient Rome*, vol. 2 [Baltimore 1936], 401ff). I hope to explore this elsewhere.