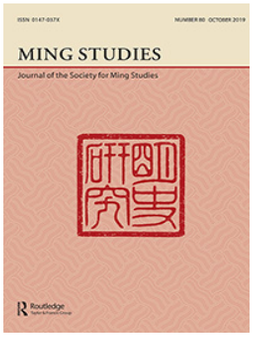


Routledge
Taylor & Francis Group

Ming Studies

ISSN: 0147-037X (Print) 1759-7595 (Online) Journal homepage: https://www.tandfonline.com/loi/ymng20

Measuring Reliability In The Wartime Transport of Provisions: The Case of Mao Yuanyi (1594–1641)

Masato Hasegawa

To cite this article: Masato Hasegawa (2019) Measuring Reliability In The Wartime Transport of Provisions: The Case of Mao Yuanyi (1594–1641), Ming Studies, 2019:80, 2-30, DOI: 10.1080/0147037X.2019.1648088

To link to this article: https://doi.org/10.1080/0147037X.2019.1648088

Published online: 24 Oct 2019.

Ming Studies, 80, 2–30, October 2019

MEASURING RELIABILITY IN THE WARTIME TRANSPORT OF PROVISIONS: THE CASE OF MAO YUANYI (1594–1641)

Masato Hasegawa

Max Planck Institute for the History of Science, Berlin, Germany

A military strategist and advisor, Mao Yuanyi (1594–1641) was one of the most prolific writers of the late Ming period on military matters and participated in the Ming war against the Jurchen in Liaodong in the early seventeenth century. In his seminal study on the conduct of war, the Records of Military Preparedness (Wubeizhi), he exhaustively discussed the costs and benefits of the transport methods available at the time, including carts, pack animals, and water transport. Among all the transport methods that he considered, Mao clearly favored what he called "human transport" (renyun), which exclusively relied on the labor of human bearers. By drawing on Mao's writings on the transport of provisions, this study analyzes his forceful argument in favor of employing human labor and illuminates the practices of organizing wartime logistics. It also sheds light on the manner in which the costs and benefits of transport methods were being evaluated and how the notions of efficiency and reliability came into play in calculations concerning transport in the late Ming period.

Keywords: *Mao Yuanyi, late Ming military logistics, Liaodong, technology, human labor, reliability*

Introduction

When we peruse scholarly writings of sixteenth- and seventeenth-century China on military matters, we often encounter extensive discussions of logistical and provisioning challenges.[1] Whenever a military conflict erupted, the task of provisioning troops inescapably confronted those who found themselves—willingly or otherwise—in the position of planning and overseeing military campaigns. While their careful planning was essential to transporting provisions successfully, of even greater importance was to coordinate the work of countless seamen, bearers, carters, and animals, who shouldered the physical burden of the transport efforts. Among them, according to late Ming sources, human bearers in particular played a critical role in military transport. During

DOI 10.1080/0147037X.2019.1648088

the Japanese invasion of Korea (1592–1598), for instance, a Ming official was instructed to transport grain for Ming troops who had been deployed to fight against the Japanese by reassigning 10,000 soldiers unfit for combat, with 200 men positioned in every ten *li* 里 (5.8 km) to cover a total distance of 500 *li* (288 km).[2] Meanwhile, for the purpose of transporting provisions, Chosŏn officials received royal approval for implementing a method of mobilizing local men and monk soldiers. Under this method, captains were designated in each unit of ten men, and to each group of 200 men were assigned supervising officials.[3] In both of these cases, the sources refer to a "method" (Ch. *fa*, Kr. *pŏp* 法) or "principle" (Ch. *zhi*, Kr. *che* 制) of mobilizing a large number of humans for military transport, indicating that there existed precedents of and established ideas about using human labor for transport. During the late Ming period, perhaps no one studied such use of human labor more methodically than Mao Yuanyi 茅元儀 (1594-ca. 1641), who read avidly the military treatises of the past from an early age. Mao's erudition in military matters was noticed by the Ming scholar-general Sun Chengzong 孫承宗 (1563–1638), and Mao later served as an advisor to Sun, who as Minister of War and a Grand Secretary effectively stalled the advance of the Jurchen troops in Liaodong during the Tianqi 天啓 reign (1621–1627), and again during the early years of the Chongzhen 崇禎 reign (1628–1644).[4]

Mao Yuanyi wrote prolifically and left behind a voluminous body of works on military tactics, strategies, and logistics. For Mao, theoretical knowledge of military matters appears to have carried little meaning unless it could be implemented in practice. When in 1628 Mao presented to the recently enthroned Chongzhen emperor (r. 1627–1644) his monumental 240-fascicle (*juan* 卷) work on military affairs titled *Records of Military Preparedness* (*Wubeizhi* 武備志),[5] his earnest hope was likely that the young nineteen-year-old emperor would instantly recognize his book's practical value in light of the escalating war against the Jurchen.[6] Mao's *Records of Military Preparedness*, which has been deemed "probably the most comprehensive Chinese military compendium ever written,"[7] not only amply displays his exhaustive knowledge of past military campaigns. It also exhibits his extensive familiarity with military logistics and the latest developments in science and technology, including Western irrigation techniques and firearms. Devoting fifty-five fascicles, or over one-fifth of the entire volume, Mao carefully examined a vast array of logistical issues such as encamping, handling of firearms, and—perhaps most importantly for keeping morale among the ranks of ordinary soldiers—provisioning troops during military campaigns.

This study examines Mao Yuanyi's notions of efficiency and reliability in military logistics by juxtaposing the *Records of Military Preparedness* with some of his other writings which he produced in the early seventeenth century. Mao's careful assessments of available transport methods and his formidable argument in favor of relying on human labor offer invaluable insights into the manner in which advantages and disadvantages of disparate transport methods were evaluated and compared in early seventeenth-century China. The existing scholarship on science and technology in China has called our attention to the sophistication of China's mechanical devices and to inventions driven by the need for efficiency. In examining the mechanical structure of wheelbarrows described in early Chinese texts, for example, Joseph Needham and Wang Ling concluded that the "essence of the invention was economical." "In the wheelbarrow," added Needham and Wang, "we have an outstanding example of those many facts which undermine, and indeed overthrow, the classical European stereotype of China as a civilisation with unlimited man-

power incapable of inventing and adopting labour-saving devices."[8] The role that such labor-saving innovations historically played in economic development in China has been closely debated in the so-called "Great Divergence" debate on the relative productivity of the Chinese economy in the early modern and modern periods.[9] For instance, in assessing the structure of the rural economy in the Yantze delta region, Philip Huang emphasized that the "vast farm-labor supply removed incentives for labor-saving capitalization and dictated that change take the direction of labor-intensifying involution."[10] Meanwhile, Kenneth Pomeranz has argued that China and Western Europe were similarly on "a labor-intensive path" until the late eighteenth and nineteenth centuries, when, according to Pomeranz, the use of fossil fuels and access to New World resources in Western Europe "obviated the need to manage land intensively."[11] However, previous studies on relative productivity in China have rarely considered the manner in which human labor was compared with labor-saving devices or technologies in the late Ming period. How was the notion of saving labor discussed and implemented? How were priorities and preferences identified and established? Inquiry into these questions also requires us to examine the availability and cost of human labor in late Ming society.[12] This study's analysis centers on an argument put forward by Mao Yuanyi. But Mao's argument for the labor-intensive method of human transport not only illuminates the practices of organizing logistics during wartime. It also sheds light on the manner in which the costs and benefits of transport methods were being evaluated and how the notions of efficiency and reliability came into play in calculations concerning transport in the late Ming period.

Modes of Transport in the Records of Military Preparedness

As Mao Yuanyi opened his section on military logistics in his *Records of Military Preparedness*, he almost immediately struck a cautious note and alerted the reader that the realities of war did not always allow a swift transport of supplies and provisions:

> Since ancient times, we have sought to make sure that when armies march, provisions follow. However, when provisions must be transported a thousand *li* (576 km), the soldiers [already] have a hungry look.[13] Therefore, if war continues over an extended period, nothing is more beneficial than military colony farming (*tuntian* 屯田). If we are to open up wasteland, we cannot avoid discussing the matter of farming. Those who discuss farming attach great importance to enhancing the natural advantages of the land with human labor. A single achievement can yield twice as many profits. If military colony farming becomes constant, experienced farmers should be consulted.[14]

Focusing on the methods of military colony farming, Mao then examined the historical precedents of military colony farming. Military colony farming was an ancient form of provisioning troops, and soldiers were expected to work the land when there was no military engagement. As one of the earliest references to military colony farming, Mao cited a Warring States text and wrote that "[people] farmed for three seasons and learned military skills for one season."[15] While emphasizing the historical roots of military colony farming, Mao was also keenly aware that much had changed since ancient times, most especially in the area of irrigation techniques.

Mao detailed the irrigation techniques of drawing water from rivers, wells, and rain and snow by citing an illustrated work on irrigation titled *Western Methods of Hydraulics* (*Taixi shuifa* 泰西水法), produced at the beginning of the seventeenth century by the Jesuit missionary Sabatino de Ursis (1575–1620) with the collaboration of Xu Guangqi 徐光啓 (1562–1633).[16] Mao did not provide much commentary on the text itself. But he noted that the sections and illustrations he included—roughly three quarters of Ursis's work—were selectively chosen as they "can be of assistance to military colony farming."[17] He closed the section on military colony farming and irrigation techniques by quoting passages on water-powered mills from Wang Zhen's 王禎 *Agricultural Treatise* (*Nongshu* 農書), a widely consulted fourteenth-century work on agriculture and sericulture. While Wang Zhen's treatise contrasted dryland farming in the north with irrigated farming in the south,[18] such a distinction is not emphasized in this section of the *Records of Military Preparedness*. But Mao's choice of treatises to be included in this section not only highlights the extent of agricultural knowledge that can be amassed by studying printed materials available in the late Ming period. It also underscores, in Mao's view, the importance of agricultural knowledge in administering military logistics.

Judging from the manner in which Mao introduced the subject of military colony farming, he appears to have believed that the ultimate objective of implementing military colony farming was to prevent hunger among soldiers in distant places and obviate the need to transport provisions over a long distance. At the same time, he acknowledged that success in implementing military colony farming did not completely eliminate the need for transporting provisions. In order to provision large contingents of soldiers and animals on the move, gathered crops still had to be sent to distant encampments, and military colony farming could only be a partial solution. Furthermore, while one had to wait for a certain period before being able to harvest crops from the cultivated land, soldiers and animals could not subsist without food and water for a protracted period. In the absence of logistical support, soldiers and animals were left to live off the land, which often created more problems than it solved. Although Mao did not explicitly explain why he chose to exhaustively discuss transport methods in the *Records of Military Preparedness*, perhaps his underlying assumption was that the transport of provisions was an inescapable component of the warfare of his time.

Shifting his focus from military colony farming to the challenge of provisioning soldiers on the move, Mao then characterized the deployment of armies, large and small, as follows:

> If small armies march far, it is inevitable that we support them by transporting provisions. If large armies suddenly congregate, it is also inevitable that we support them by transporting provisions. There are only two types of transport: water and overland transport. Water transport consists of canal and sea transport, while overland transport consists of cart, mounted, and human transport.[19]

Mao's breakdown of military transport offers helpful hints about his structural understanding of the transport of provisions. It allows us to understand how Mao, one of the foremost experts on military matters of his time, conceptualized and differentiated various means of transport on waterways, by sea, and across land.

River and Sea Transport (hecao 河漕, haiyun 海運)

While Mao chose to examine canal and sea transport in the *Records of Military Preparedness*, his discussions primarily described existing navigation routes without offering extensive commentary. He also drew almost exclusively on earlier works on waterways and sea lanes. As he discussed river and canal transport, for example, Mao entirely relied on the work of Pan Jixun 潘季馴 (1521–1595), "the foremost hydraulic engineer of Ming times,"[20] who detailed the course of the Yellow River from its purported source in the mythological Kunlun Mountain to the mouth of the River in today's Zhejiang province.[21] In the section on sea transport, on the other hand, Mao relied on the illustrated geographical survey of the Ming realm by Luo Hongxian 羅洪先 (1504–1564), who in turn had based his work on an earlier geographical study by the Yuan-dynasty scholar Zhu Siben 朱思本.[22] In the *Records of Military Preparedness*, Mao introduced the four sea lanes described by Luo (see Figures 1 and 2). The first route takes the reader from Fuzhou 福州 in Fujian province to the coastal area near Jinghai Guard 靖海衛 on the southeastern tip of the Shandong peninsula. Second, one sails from Liujiagang 劉家港 near today's Shanghai to the wharf of Nuizhuang 牛壯 along the Sancha River 三叉河, the downstream of the Liao River 遼河 in today's Liaoning

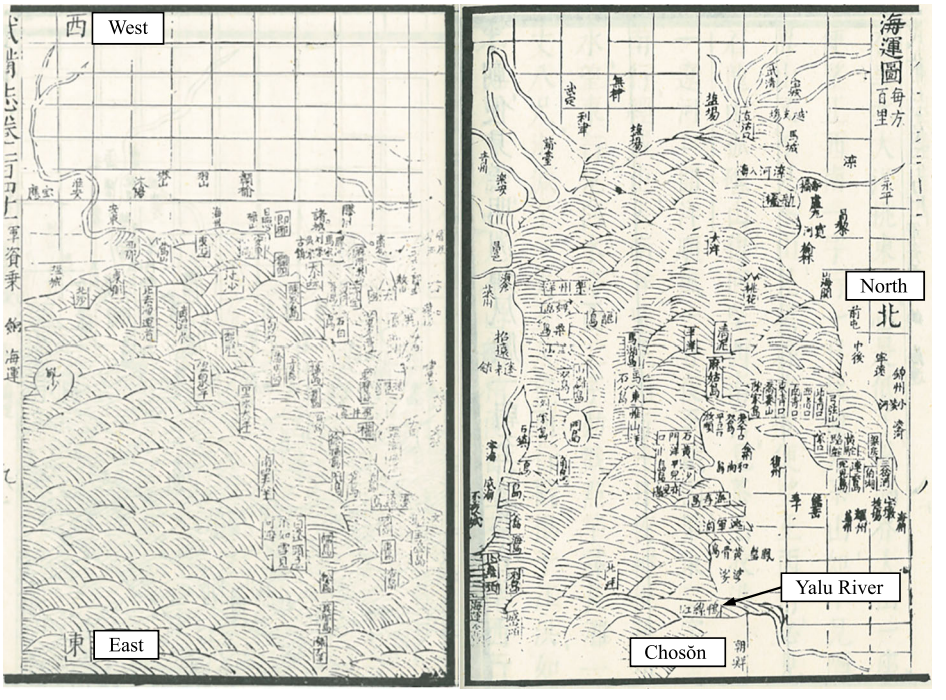


Fig. 1. Map of ports accompanying the text on sea transport in Mao Yuanyi's *Records of Military Preparedness* (*Wubeizhi*). This map views the Shandong peninsula (in the middle) from the east with the north facing the right of the page. Chosŏn Korea and the Yalu River appear in the lower right corner, and Huai'an prefecture and the Yellow River are depicted in the top left corner. (Mao Yuanyi, *Wubeizhi, juan* 141, 32:5944–5945.)

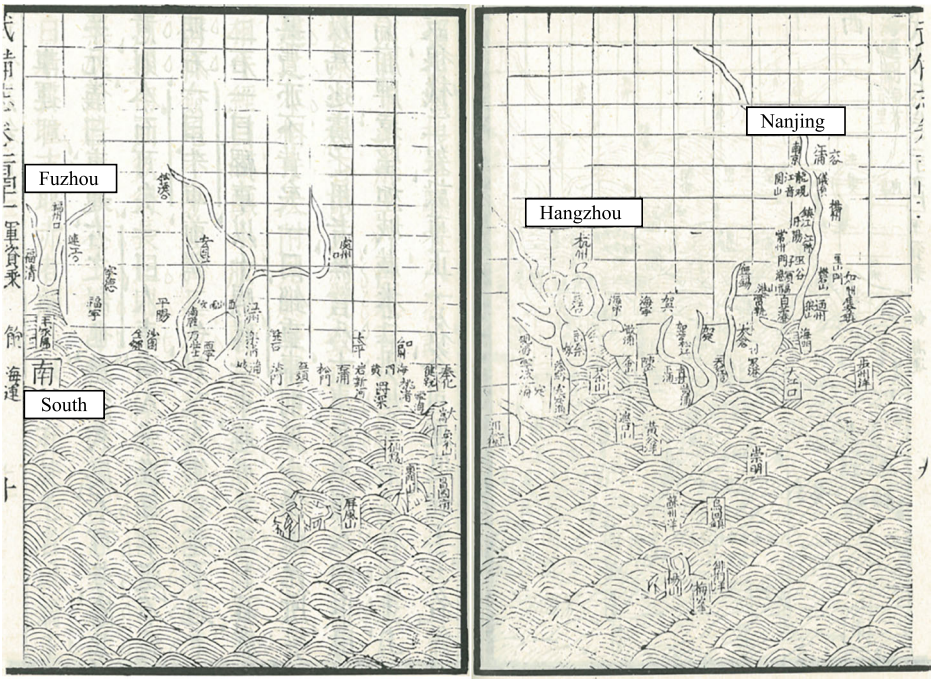


FIG. 2. Map of ports accompanying the text on sea transport in Mao's *Records of Military Preparedness* (continued). This map also views China's southeastern coast from the east, with the north facing the right of the page. It depicts Nanjing and the Yangtze River on the right and Fuzhou on the left of the page. (Mao Yuanyi, *Wubeizhi, juan* 141, 32:5946–5947.)

province.[23] Third, we journey south from Zhigu 直沽 near Tianjin to the mouth of the Yangtze River. Finally, we start at the mouth of the Liao River and reach Liujiagang at the mouth of the Yangtze River.[24] Of the four routes introduced by Luo, the second and fourth connected the Yangtze delta region with the Liaodong peninsula and were almost identical except for the direction in which they are described. Considering that the other two routes, one from Fujian to Shandong and the other from Tianjin to the Yangtze delta region, are not paired with ones in the opposite direction, it may be plausible to suggest that the sea lane between Liaodong and the Yangtze delta region held particular importance in sea transport at the time of Luo's writing, and perhaps also in Mao's mind.[25] But, similar to his section on river transport, Mao did not offer extended commentary. We are left to speculate on how Mao gauged the value of Luo's maps and descriptions of the four sea routes in light of the military challenges that the Ming faced in Liaodong at the beginning of the seventeenth century.

Overland Transport (luyun 陸運)

In stark contrast to his reliance on earlier texts in the sections on river and sea transport, Mao Yuanyi asserted himself more forcibly in his assessment of overland transport methods. Whenever he consulted the past literature on military matters in the *Records of Military Preparedness*, Mao carefully distinguished quoted passages

from his own writing. While little commentary is included in the sections on river and sea transport, all of the three sections on overland transport contain Mao's detailed analysis. In addition, Mao entirely omitted descriptions of overland routes across the Ming realm. Had he wished to include them, the wide availability of route books during the late Ming period would certainly have made the task feasible.[26] Similarly, for reasons that are not clear, he chose not to include maps of overland transport routes. Instead, Mao solely focused on carefully analyzing the merits and costs of overland transport methods. Perhaps reflected in this contrast is the likelihood that Mao had acquired greater familiarity with the overland transport of provisions, in comparison to his experience of—or interest in—water transport. Despite their relative brevity, the sections on overland transport in the *Records of Military Preparedness* meticulously address technical and practical concerns, such as costs, capacity, efficiency, and reliability. Mao's assessment of overland transport methods, therefore, allows us to take a close look at the military transport of provisions during the late Ming period.

Cart Transport (*cheyun* 車運)

Mao's analysis of overland transport consists of three sections, with each corresponding to cart, mounted, and human transport. "Cart transport is an ancient principle (*zhi* 制)," wrote Mao as he opened his section on cart transport. "Its method (*fa* 法) has long been neglected and cannot be examined," he added, "and as for examining its purposes, we can only examine [what goes on] today."[27] This opening passage is immediately followed by his assessment of four types of cart transport that were presumably in use at the time of his writing. Also provided are numerical figures indicating how heavy a load each mode of transport could transport. The first was what he termed the "human-cart" (*renche* 人車), which was driven and controlled by carters. Two persons pulled and pushed the cart, and it could transport a load of up to four bushels (*shi* 石, approx. 414 ℓ). Unfortunately, Mao's description of the hand-held cart is not accompanied by any illustrations. But his contemporary Song Yingxing 宋應星 (1587–ca. 1666) in his *Exploitation of the Works of Nature* (*Tiangong kaiwu* 天工開物) provided commentary on the single-wheeled cart with illustrations.[28] Song noted that this so-called "single-wheeled push-cart (*dutuiche* 獨推車) of the south can be managed by the strength of a single person. It can carry a load of two bushels (207 ℓ). It must stop whenever it encounters a pit on the ground. The farthest it can travel is merely 100 *li* (58 km)."[29] Judging from the difference in the volume of load, Song's single-wheeled push-barrow was likely smaller than Mao's hand-held cart, which required the labor of two persons. Nevertheless, Song's illustration and description provide vivid pictorial images of late Ming carts, which Mao might have observed in his native Zhejiang province, or in the Liaodong region (see Figure 3).

The second type of cart that Mao discussed in the *Records of Military Preparedness* was the "ox-cart" (*niuche* 牛車). The ox-cart was powered by two oxen, and two persons controlled the movement of the oxen and the cart. This type of cart, according to Mao, could carry a load of up to twelve bushels (1.2 kℓ), three times as much as the human-cart driven by two people.[30] Thirdly, Mao wrote that the "mule-cart" (*luoche* 騾車) was led by a team of ten mules and could carry a load

FIG. 3. *Left*, a single-wheeled cart pushed by one person employed in the south; *right*, a single-wheeled cart pushed by one person and drawn by two donkeys. (Song Yingxing, *Tiangong kaiwu*, 2:42–43.)

of up to thirty bushels (3.1 kℓ). In relative terms, the mule-cart could carry more than twice as much load as the ox-cart, and over seven times as much as the human-cart. The mule-cart, however, was clearly not Mao's preferred method. From the point of view of cost efficiency, he was clearly of the view that the mule-cart did not offer any advantage over the other types of cart. While Mao did not explain in detail, he emphasized that "its costs are incalculable."[31]

The fourth and final type of cart transport, according to Mao's categorization, was the so-called "supply-cart" (*zizhongche* 鎡重車). As Mao explained in the *Records of Military Preparedness*, the invention of the supply-cart is normally attributed to the Ming military commander Qi Jiguang 戚繼光 (1528–1588), who helped rebuild the Ming defenses in both south and north China. The functional purposes of the supply-cart were twofold. Tactically, its wooden structure could provide cover for soldiers on the battlefield; logistically, it could transport a significant volume of supplies and provisions for armies deployed away from urban centers or sites of agricultural production. According to Qi's original design, a team of

eight mules drew each wagon, and eighty supply carts formed a division (*ying* 營) (see Figure 4). On top of the cart was placed a large single-sided shield (*pianxiangpai* 偏廂牌), which "resembled a city wall when seen from a distance."[32] Qi added that his "supply-cart" could transport twelve and a half bushels (1.3 kℓ) of grain, beans, and preservable food, slightly exceeding the capacity of Mao's ox-cart. Thus, one division of supply-carts could transport a combined load of 1,000 bushels (104 kℓ) of food, which was deemed sufficient to feed 10,000 men and horses for three days.

On balance, Mao Yuanyi concluded that the ox-cart was preferable to all the others as far as cart transport was concerned. As he drew such a conclusion, he found an encouraging support in the *Classic of Changes* (*Yijing* 易經), one of China's most canonical texts. "The ancient saying goes," wrote Mao referring to a passage in the *Classic of Changes*, "horses are used to reach a distant place, while oxen are used to transport a heavy load. Thus, oxen are the basis of cart transport."[33] Unfortunately for our analysis, he did not address the question of how widely each cart device was being used for military or other purposes. Nor did he discuss climatic or terrain conditions under which each type of cart could and could not function as designed.

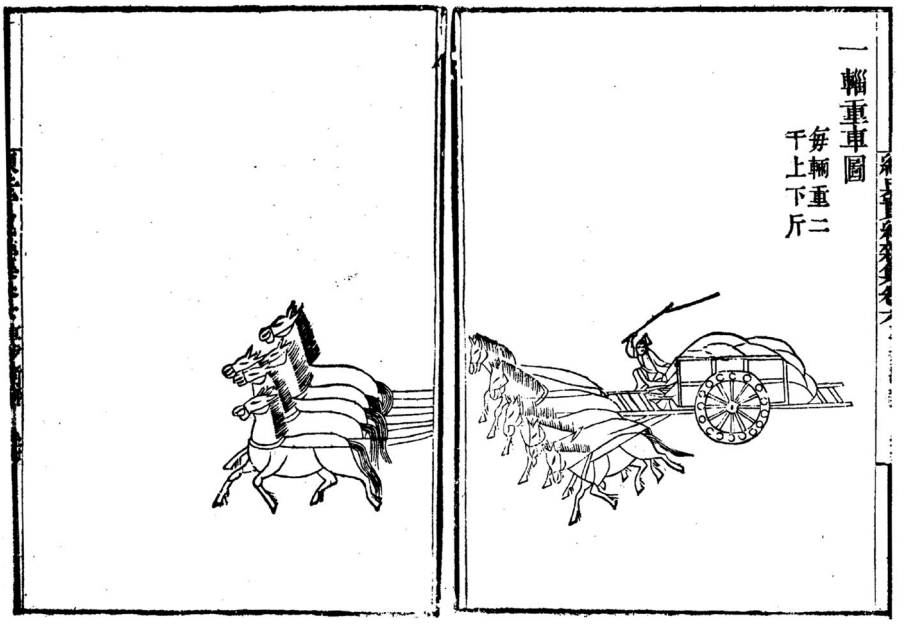


Fig. 4. A mule-led "supply-cart" depicted in Qi Jiguang's *Practical Account of Military Drill* (*Lianbing shiji*). The caption reads: "Each cart weighs about 2,000 catties (approx. 1,194 kg)." While the harnesses of the five mules in the front are not connected to the mules in the rear in this illustration, Qi Jiguang wrote in the accompanying passage that that a team of eight mules led a cart loaded with military provisions and supplies. In another section of the text, Qi noted that each cart was led by ten mules, as depicted in this illustration. (Qi Jiguang, *Lianbing shiji, juan* 1, 19:111; *Lianbing shiji, Zaji, juan* 6, 19:732–733.)

Mounted Transport (*qiyun* 騎運)

Turning to the next mode of overland transport, Mao focused his attention on the method involving three members of the horse family: horses, mules, and donkeys. Although Mao did not explicitly explain how those draft animals differed from those employed for cart transport, the very distinction that Mao drew between cart and mounted transport implies that these were pack animals, which carried heavy loads either on their backs or on pack saddles. Of the three sections concerning overland transport in the *Records of Military Preparedness*, the one on mounted transport is the shortest, merely consisting of three lines. Moreover, Mao's commentary makes it evident that he considered mounted transport to be both costly and inefficient. "There are three types of mounts," noted Mao as he explained how they differed from one another in terms of the volume of load they could carry. "Horses and mules are capable of carrying up to one and a half bushels (155 ℓ), while donkeys are capable of carrying up to one bushel (104 ℓ)."[34] Compared with the four types of cart transport that Mao discussed, namely the human-cart, ox-cart, mule-cart, and supply-cart, the volume of load which pack animals could carry indeed appear relatively small. According to Mao's own estimates, even the smallest of the four—the hand-held cart driven by two carters—could transport a load of up to four bushels (414 ℓ), nearly three times as much as a pack horse.

In addition, in order to be able to reliably travel a long distance with loads, every mount had to be fed with an adequate amount of fodder each day. Sources indicate that during the Ming period cavalry horses were provided with a daily average of three pints (*sheng* 升) (3.1 ℓ) of beans and one bundle of grass, weighing about fifteen catties (*jin* 斤) (9 kg).[35] Without adding further commentary on mounted transport, Mao then almost bluntly stated that "while the costs are considerable, the load that can be transported is small. This is not a fine method. [Only] when there is no alternative should this method be used."[36] Interestingly, Mao closed this section on mounted transport by noting that "camels of the northwestern frontiers are capable of fulfilling the duties of several horses."[37] No mention is made of whether he had personally seen camels transporting heavier loads. According to a memorial submitted by a Vice Minister of Revenue in 1619, however, the then Governor of Liaodong appears to have proposed employing camels to transport provisions, for "a camel can carry three times as much load as a horse or donkey but eats no more than a horse or donkey."[38] Mao was perhaps aware of such a discussion among Liaodong officials and might have considered the use of camels in the overland transport of provisions in the region. But purchasing or hiring a sufficient number of camels perhaps proved difficult. Mao concluded that camels could not become a viable alternative to horses because "they cannot be obtained in large numbers."[39]

Human Transport (*renyun* 人運)

The last of the three modes of overland transport examined by Mao Yuanyi employed neither the principles of mechanical engineering nor the physical stamina of pack animals. It solely relied on human labor. Of all the three methods, Mao clearly favored this method of transport. Well versed in literature on military matters, Mao was keenly aware that there existed in China a historical precedent for transporting military supplies and provisions by coordinating the

work of human bearers. He found such an example in the biography of the Yuan-dynasty general Dong Tuanxiao 董摶霄 (d. 1358) in the *Standard History of the Yuan Dynasty* (*Yuanshi* 元史). Included in Dong's biography is the following proposal that he presented to the Yuan court in 1356, when widespread insurgencies were seriously undermining the Yuan emperor Shundi's 順帝 claim to power. The matter in question was the transport of provisions in the strategically vital region of Huai-Hai 淮海, where the Huai River met the Yellow River in central China. Among the key localities in the region was the coastal prefecture of Haining 海寧, located to the east of Xuzhou 徐州:

> In the area around Haining Prefecture, boats cannot pass, and military provisions can only be transported overland. But the people of the entire Huai-Hai region have suffered from repeated banditry, and we should provide comfort. For the time being, soldiers should be ordered to transport provisions.[40]

Dong's primary objective was to transport provisions in the lowlands of today's Jiangsu province. But he assessed that water transport was not an option, and banditry had already depleted the resources of the local communities. In this context, Dong proposed employing the following method of transport, making the most of the readily available labor of his soldiers:

> If everyone walks ten paces (16 m), then thirty-six people can cover the distance of one *li* (576 m). 360 people can cover ten *li* (5.8 km), and 3,600 people can cover 100 *li* (58 km). Everyone carries four pecks (*dou* 斗) (41 ℓ) of husked grain (*mi* 米) in a lined cloth sack, which is sealed and marked with a seal. People do not rest their shoulders, nor does husked grain touch the ground. People are lined up so that they form a straight line. Everyone walks 500 laps and a total of twenty-eight *li* (16 km) a day. [In other words,] everyone walks fourteen *li* (8 km) with a load and another fourteen *li* without, and we can transport a total of 200 bushels (21 kℓ) of husked grain a day. If a pint (1 ℓ) of husked grain is distributed [per person], we can provide for 20,000 people. This is the procedure (*shu* 術) of transporting provisions over 100 *li* a day.[41]

In the *Records of Military Preparedness*, Mao only quoted this latter portion of Dong's proposal, which detailed his method of transport relying on human labor. Mao quietly left out the first portion of the passage, where Dong succinctly explained the geographical and socio-political context of his proposal.

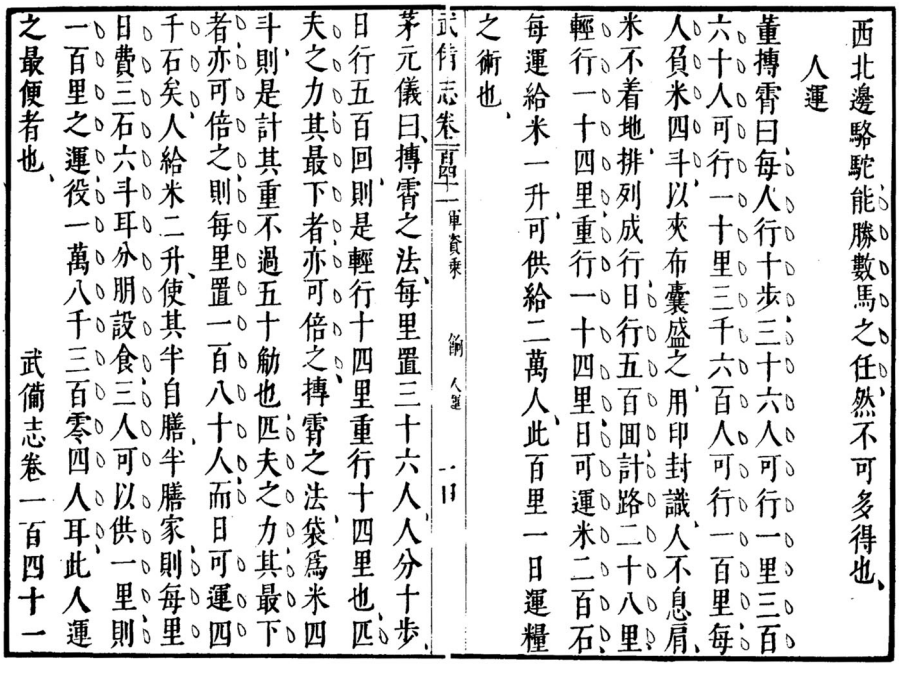
As we have seen above, Dong's biography in the *Standard History of the Yuan Dynasty* illuminates the two central premises of his transport method. First, enlisting the labor of local residents in the Huai-Hai region would further aggravate their suffering caused by banditry and social disorder. Second, in place of local residents, 3,600 soldiers were available and could be assigned the task of carrying provisions as bearers amidst growing threat posed by rebel forces in the region. Mao was likely aware of these premises of Dong's memorial as he wrote elsewhere that soldiers not assigned to combat duty would be an ideal source of labor for the purpose of transporting provisions.[42] In his discussion of human transport in the *Records of Military Preparedness*,

however, Mao did not address the issue of labor availability, at least explicitly. Instead, he focused on the technical aspect of Dong's proposal. Without specifying who were to serve as bearers, he went on to suggest a modification to Dong's design and argued that the bearers should be able to substantially increase their workload:

> According to [Dong] Tuanxiao's method, thirty-six people were assigned to each *li*, and everyone was responsible for ten paces. If they walked 500 laps a day, that meant that everyone walked fourteen *li* with a load and another fourteen *li* without. Even the least strong should be able to double the distance. According to [Dong] Tuanxiao's method, each sack contained four pecks (41 ℓ) of husked grain. If we consider its weight, it does not exceed fifty catties (30 kg). Even the least strong among the men should be able to double the volume of his load.[43]

On the one hand, Mao appears to have acknowledged the overall validity and effectiveness of Dong's approach. On the other hand, he clearly felt that Dong did not optimize the use of men's physical resilience. Thus, he suggested that all bearers should be able to increase their workload fourfold.[44] Still, this was not the sole modification of Dong's method that Mao put forward (see Figure 5).

Perhaps perceiving that the scale of the military threat that the Ming faced in Liaodong was different from Dong's challenges in the Huai-Hai region centuries earlier, Mao further multiplied Dong's figures of bearers by a factor of five. That is to say,


西北邊駱駝能勝數馬之任然不可多得也、

人運

董摶霄曰每人行十步三十六人可行一里三百六十人可行一百里每人負米四斗以夾布囊盛之用印封識人不息肩米不着地排列成行日行五百回計路二十八里輕行一十四里重行一十四里日可運米二百石每運給米一升可供給二萬人此百里一日運糧之術也、

武備志卷一百四十一 軍資乘 餉 人運 一一

茅元儀曰摶霄之法每里置三十六人人分十步日行五百回則是輕行十四里重行十四里也匹夫之力其最下者亦可倍之摶霄之法袋爲米四斗則是計其重不過五十觔也匹夫之力其最下者亦可倍之則每里置一百八十人而日可運四千石矣人給米二升使其半自膳半膳家則每里日費三石六斗耳分朋設食三人可以供一里則一百里之運役一萬八千三百零四人耳此人運之最便者也、

武備志卷一百四十一

Fig. 5. The page explaining Mao's method of human transport in the *Records of Military Preparedness*. Note emphasis marks in the shape of water drops on the right-hand side of the text. (Mao Yuanyi, *Wubeizhi, juan* 141, 32:5955–5956.)

five teams of thirty-six bearers, or a total of 180 bearers, formed five separate straight lines in each *li* to transport provisions. Mao explained, "if we assign 180 bearers to each *li*, we can transport 4,000 bushels (414 kℓ) a day."[45] With thirty-six bearers assigned to every *li*, Dong's original method enabled the transport of 200 bushels (21 kℓ) a day. With 180 bearers assigned to every *li*, therefore, the total volume of transported grain would increase fivefold to 1,000 bushels (104 kℓ). Then, if all bearers could double both the distance that they walked and the volume of grain that they carried, the total volume would further increase fourfold—at least in theory—to 4,000 bushels a day.

In the *Records of Military Preparedness*, Mao did not directly discuss the practicability of his method of human transport. As shown in the introduction of this study, however, sources suggest that the method of human transport had indeed been implemented for military transport in the late Ming period. In the case of the Ming official in charge of logistics during the Japanese invasion of Korea at the end of the sixteenth century, for example, he was instructed to position 200 soldiers unfit for combat every ten *li*—or twenty soldiers every *li*—over a distance of 500 *li* (288 km) for the purpose of transporting provisions and supplies.[46] Twenty men assigned to each *li* were even fewer than thirty-six men assigned to each *li* under Dong Tuanxiao's method. Perhaps such an adjustment was oftentimes necessitated by the realities of war and a lack of human labor in wartime society. As far as we can judge from Mao's writings, he appears to have firmly believed that he would be able to transport 4,000 bushels of grain a day by assigning 180 men to each *li*, five times as many as under Dong's method, and nine times as many as under the method indicated in the case above during the Japanese invasion of Korea.

In the passages that followed, Mao further elaborated on his method of human transport and underscored its advantages over the other transport methods. He calculated the costs of implementing his method of transport and provided the following estimates:

> If we pay each person two pints (2 ℓ) of husked grain and have him eat a half for himself and provide for his family with the rest, the daily expenses for each *li* is merely three bushels and six pecks (362 ℓ). If we make groups for meals, three cooks can feed [those assigned to] each *li*. Thus, a transport over 100 *li* (58 km) only requires the labor of 18,304 people.[47]

To our eyes, the task of enlisting the willing cooperation of over 18,000 individuals may seem extremely challenging. Mao, however, undoubtedly considered this number to be relatively small. Inserting the particle "only" (*er* 耳) twice into the passage, he stressed the relative smallness of the figures both in terms of the total wages and in terms of the number of laborers necessary in order to implement his method of transport. With all things considered, Mao concluded that "this is the most convenient aspect of human transport."[48]

A Case for Human Transport

For Mao Yuanyi, who personally participated in the Ming war against the Jurchen armies in Liaodong in the early seventeenth century, the transport of provisions was

not merely a matter of intellectual exercise. He presented a forceful argument in favor of human transport at a time when Nurhaci's consolidation of power in Liaodong was gathering momentum at the expense of the Ming hold over the region. Especially in the aftermath of the crushing defeat of the Ming at Sarhu in 1619,[49] deciding on the manner in which supplies and provisions should reach the encampments of Ming troops likely assumed renewed importance. Mao might have felt that any decision on the method of transport could potentially translate into the crucial difference between victory and defeat on the front lines.

In the *Records of Military Preparedness*, however, Mao presented his case for human transport in a rather general form, perhaps in part because he sought to broaden the appeal of his magnum opus. To take one example, Mao did not link his assessment of various transport methods to any specific geographical regions. Mao's choice to leave out the first portion of Dong Tuanxiao's proposal further adds to the impression that he intentionally removed regional references from his section on human transport in the *Records of Military Preparedness*. Consequently, Mao's case for human transport leaves the reader searching for further context as to why he considered human transport to be the most efficient means of wartime transport, compared with all the other methods considered in the *Records of Military Preparedness*.

As if to address such concern on the part of the reader, Mao provided a more thorough discussion of human transport in one of his collected essays titled *Daring to Speak* (*Maoyan* 冒言). In his own preface to the collection, Mao explained that he had completed the essays in 1618 in his mid-twenties, well before he participated in the Ming war in the Liaodong region.[50] Although it remains difficult to determine whether these essays preceded or followed his writing of the *Records of Military Preparedness*, the first two essays—one on military colony farming and the other on human transport—specifically address the military situation and challenges in the Liaodong region.[51] This indicates that the Liaodong region had long held a prominent place in Mao's thinking about military transport and logistics.

Duration and Wages

In *Daring to Speak*, Mao's essay detailing the method of human transport is simply titled "Human Transport" (*renyun* 人運). In examining this essay, we quickly realize that Mao's method of human transport was clearly intended for the Ming war against the Jurchen in the Liaodong region. As in the *Records of Military Preparedness*, Mao also chose to begin his discussion by introducing the method proposed by the Yuan general Dong Tuanxiao. But what clearly distinguishes this essay from the *Records of Military Preparedness* is that Mao carefully took note of the critical difference between Dong's challenges in the low-lying plains in today's Jiangsu province and those of the Ming across the vast mountainous terrain of Liaodong at the beginning of the seventeenth century. Almost dismissing Dong's method as outdated, Mao in this essay introduced his subject matter in a forthright manner:

> The method of human transport has been in existence since ancient times. According to historical records, it was started by Dong Tuanxiao, a man of the Yuan period. However, if we wish to implement his method today, it is certainly bound to fail. What Dong Tuanxiao proposed was to transport

> [provisions] in Haining. Few men were involved, and the distance was short. He used soldiers to transport military [provisions] and simply fulfilled what was needed.[52]

In contrast to the *Records of Military Preparedness*, Mao in this essay immediately highlighted the limitations of Dong's method. With the ongoing conflict in the Liaodong region in mind, Mao indicated that Dong's plan—covering the distance of 100 *li* with 3,600 bearers—was an appropriate measure under Dong's specific circumstances. But it was not a method that could be applied directly to his challenges at the beginning of the seventeenth century.

Mao responded to his challenges in Liaodong by devising his own method of transport based on the foundation laid by Dong some two and a half centuries earlier:

> The method [of transporting provisions] in Dongning Circuit [of Liaodong] has yet to be implemented uniformly. Now, if we focus on the two Circuits discussed by the Military Commissioner (*jinglüe* 經略), there is a distance of 240 *li* (138 km) to Liaohai 遼海 Circuit and 210 *li* (121 km) to Hai-Gai 海盖 Circuit.[53] The Military Commissioner has mentioned that there would be an annual need of 1,120,000 bushels (115,920 kℓ) of husked grain and beans, and that the costs would total 588,750 taels [of silver]. We have yet to encounter the following problems: carts breaking down, oxen collapsing, and sacks being swapped. If these problems were to occur, nothing would be better than proposing human transport.[54]

While Mao in this essay does not appear to have directly leveled criticism at the Military Commissioner, his writing makes plainly evident how much the two men disagreed over how best to transport military supplies and provisions in Liaodong. According to a letter that Mao wrote to a friend in 1621, the Military Commissioner had taken a position in favor of employing ox-carts in Liaodong. Mao explained that each ox-cart required a team of two oxen and two carters to operate, perhaps resembling one of the cart vehicles depicted in Song Yingxing's *Exploitation of the Works of Nature* (see Figure 3, *right*). Mao, on the other hand, did not share the Military Commissioner's favorable views on the ox-cart. He firmly held that cart transport was both costly and inefficient.

For Mao, the immediate logistical challenge was to transport provisions over a combined distance of 450 *li* in the area under the jurisdiction of Liaohai and Hai-Gai Circuits in Liaodong.[55] Before detailing his own method, Mao once again briefly explained the basic ideas of Dong's human transport: thirty-six bearers were assigned to each *li*, and everyone walked twenty-eight *li* a day to transport a total load of 200 bushels. As we have seen above, Mao argued that bearers could increase their workload fourfold. In other words, while Dong called for a transport of 200 bushels a day, Mao expected each line of bearers to transport a total of 800 bushels (83 kℓ) a day. With five teams of thirty-six bearers assigned to each *li*, therefore, Mao's method theoretically enabled a daily transport of 4,000 bushels (414 kℓ). In term of the volume of load that could be transported, this was where Mao left the reader in the *Records of Military Preparedness* without providing additional variables.

Between Mao's discussions of human transport in the *Records of Military Preparedness* and *Daring to Speak*, one of the notable differences is that he addressed the issue of time and duration in his essay in *Daring to Speak*. Mao was clearly responding to logistical challenges not merely in the short term, but also in the long term. Over the course of a year, which consisted of roughly 354 days according to the lunar calendar, or about 384 days when there was an intercalary month, Mao expected the transport of provisions in the Liaodong region to continue for 280 days, or nine and a half months. At the rate of 4,000 bushels of grain per day, this meant that the transport of 1,120,000 bushels (115,920 kℓ) of grain was possible annually. Mao did not explain how he arrived at the expected duration of 280 days for the transport of military provisions. Nor did he specify whether he expected the bearers to work continuously for 280 days, or with days of rest in between. Perhaps Mao had in mind the ancient passage about dividing the four seasons for farming and military training, which he cited in his section on military colony farming in the *Records of Military Preparedness*. The passage indicated that in ancient times people farmed for three seasons in a year and learned military skills for one season. Scholars have long understood this passage to mean that while the three seasons of spring, summer, and autumn were apt for farming, the winter months permitted people to spend time away from the fields and hone their military skills. Mao might have borrowed this framework of dividing a year into two groups and envisioned three seasons, or roughly 280 days, of military transport. He might have also assessed that the transport of provisions was possible only for 280 days due to icy climatic conditions in Liaodong's winter, or that one million bushels of grain transported over 280 days was sufficient to provision the Ming soldiers stationed in the region for the entire year. Mao's text also remains silent as to how he expected the bearers to spend the remainder of the year. One thing that is clear from his writings, however, is that he did not expect the bearers to receive wages when they were not transporting provisions.

As far as wages were concerned, Mao calculated that two pints (2.1 ℓ) of husked grain was needed daily for each bearer. Based on this assumption, the costs of transporting provisions over the distance of 450 *li* with the labor of 81,000 bearers—or 180 bearers in each *li*—totaled 1,620 bushels (160 kℓ) of husked grain a day and 453,600 bushels (44,770 kℓ) over 280 days.[56] Mao further argued that his method of transport could also be applied to transporting grass fodder for a shorter duration of 227 days. He noted that one bundle of grass weighed fifteen catties (9 kg) and that each person should be able to take seven bundles at a time. This meant that everyone was expected to walk ten paces with a total load of 105 catties (63 kg). If we assume that one could enlist the labor of the same number of bearers over a distance of 450 *li*—81,000 in total—as for the transport of grain, this method would have enabled the transport of nearly eight million bundles of grass fodder over 227 days. As in the transport of grain, each bearer was to receive a daily wage of two pints (2.1 ℓ) of husked grain, and Mao expected the total expenses to be 367,540 bushels (36,276 kℓ) of husked grain.[57]

Social Ramifications of Human Transport

Apart from its geographical focus on Liaodong and consideration of duration, Mao's essay in *Daring to Speak* also differs from the *Records of Military*

Preparedness in that it considered the resulting effects of human transport on the region's economy. Noting that "the people of the Liao region must eat millet (*su* 粟) of the Liao region,"[58] Mao wrote that if Ming armies transported their own provisions using the method of human transport, they would be able to reduce the likelihood of disrupting the balance of supply and demand in local grain markets:

> Now, if officials send out 450,000 [bushels of grain], it means that 450,000 bushels will remain among the people. Should there be an additional supply of 450,000 bushels, we will certainly be able to purchase grain at fair prices. We would not need 300,000 taels; there would be no use for carts or oxen. The only inevitable item would be cloth sacks.[59]

Rounding down the figure of 453,600 bushels that could be transported over 280 days, Mao argued that his method of human transport would not only enable a reliable transport of provisions, but also help stabilize local grain prices in the Liaodong region. As a positive consequence, according to Mao, stable grain prices would also guarantee that, when necessary, officials would be able to locally procure grain at fair prices.

At the same time, Mao was probably aware that his method of human transport posed inherent risks. By design, human transport required a substantial number of hired hands, and preventing fraud among the bearers was a serious challenge. In his essay, Mao repeatedly underscored the need to securely seal every cloth sack, presumably in an effort to thwart attempts of deception on the part of the bearers. He did not describe the exact ways in which bearers could swap sacks in secret for personal gains. The practice of "swapping sacks" (*yidai* 易袋), however, is mentioned twice in this relatively brief essay. It may indicate that actual cases of fraud had indeed alerted Mao to the risk of losing grain in transit. Perhaps he felt that dishonesty among the bearers could seriously derail the Ming effort to provision its soldiers in Liaodong, and that preventative measures had to be put in place. Mao likely knew, however, that completely rooting out fraudulent practices was extremely difficult, if not impossible. 81,000 bearers, spaced ten paces apart over the distance of 450 *li*, could not constantly come under the watchful eyes of officials, some of whom might have also chosen to collude with bearers. Mao could only hope that clearly marking every sack with an official seal would dissuade the bearers from cheating. "If the sacks are marked and sealed securely and reach the granaries where they should be unloaded," noted Mao, "we can prevent the evil practice of swapping sacks."[60]

We also know that Mao was paying attention to the Sino-Korean borderland, for he discussed the ground conditions of Kuandian 寬奠 and Aiyang 靄陽 Forts (*bao* 堡) on the western bank of the Yalu River (see Figure 6).[61] The strategic importance of the two forts was soon to assume added importance as the Jurchen gained control of the area and began to seriously challenge the defenses of both the Ming and the Chosŏn. According to the Chosŏn official Kim Sŏkchu 金錫胄 (1634–1684), who strongly advocated an anti-Manchu position at the Chosŏn court during the reigns of King Hyŏnjong 顯宗 (r. 1659–1674) and Sukchong 肅宗 (r. 1674–1720), Kuandian and Aiyang Forts were located opposite from Ch'angsŏng 昌城 and Pyŏktong 碧潼 on the Chosŏn side of the border and

FIG. 6. Map of Ming Liaodong. This map was created by Nung-yao Lin.

could become bases for a military attack against Korea. Kim Sŏkchu also noted that the terrain in the areas to the south of Ch'angsŏng was relatively less precipitous than in the surrounding areas, and that the rivers there flowed slowly. For these reasons, according to Kim, the Chosŏn armies chose to march north through this region to cross the Yalu River in 1618, on the eve of the Battle of Sarhu. It was also through this region that Jurchen armies launched their invasion of Korea in 1627, and again in 1636.[62] From the point of view of Mao Yuanyi, however, such relative ease of movement for large armies did not automatically translate into the ease of movement for provisions. "In the areas surrounding Kuandian and Aiyang Forts," he wrote, "we are unable to use the cart. If we were to use pack horses (*matuo* 馬駄), the costs would be even greater. If we employ human labor, we will need no horses."[63] By emphasizing that the terrain of the border region along the Yalu River made the use of the cart practically unsuitable, Mao provided—conveniently for his argument—yet another reason to adopt his method of human transport.

The Efficiency and Reliability of Human Transport

Mao Yuanyi's writings suggest that there existed strong support for the use of carts among Ming officials at the time of the war against the Jurchen. Mao clearly felt that he had to persuade such advocates of cart transport of the advantages of using human labor. In the final section of his essay on human transport in *Daring to Speak*, he mounted a stout defense of his method of human transport, most likely aimed at the cautious critics of the method:

> Those who caution against human transport merely question whether there will be a sufficient number of people. What they do not know is that a proposal has been made to hire 30,000 carters [for cart transport], not including public and private petty laborers (*zayi* 雜役) who cut grass or feed oxen. Now, [under the method of human transport] we will only need 81,000 bearers over the vast expanse of the two Circuits [of Liaohai and Hai-Gai]. If we separate the bearers into groups and provide meals, and if three cooks feed those assigned to each *li*, in total just over 1,000 petty laborers would be needed. Why should we worry that people will be insufficient in number?[64]

Mao maintained that human transport would be far less costly than cart transport. Assuming that each cart required the labor of two oxen and two carters, hiring 30,000 carters essentially entailed hiring 15,000 carts and 30,000 oxen. In Mao's reasoning, if one considered the daily expenses of feeding the oxen, providing for the carters, and performing routine maintenance of the carts, no one could choose cart transport over human transport.

With respect to the challenge of enlisting the labor of a significant number of bearers, Mao's apparent optimism might have derived in part from the expectation that a large portion of the garrisoned soldiers in Liaodong, such as Liaoyang 遼陽 and Guangning 廣寧, could be reassigned to transport duties.[65] At the same time, Mao made an economic argument that his wage structure had greater appeal than the one proposed by the proponents of cart transport. Even in the absence of military labor, Mao would likely have remained confident that local residents in Liaodong would willingly provide their labor for wages. According to Mao, his critics proposed to hire carters by offering three-hundredths of a silver tael (1 g) per person a day. Over the course of a year, the carters were expected to work and receive wages for eight months, slightly shorter than under Mao's method of human transport. Thus, each carter would have earned nine-tenths of a tael (34 g) of silver a month and seven taels and two maces (267 g) by the end of the eighth month.[66] At the time, a peck of grain (10 ℓ) was valued at one mace and seven-hundredths of a tael (6 g). Based on this price, the annual wage of seven taels and two maces would have allowed one to purchase forty-two pecks and three pints (439 ℓ) of grain, or an average of less than two pints a day. Under Mao's method, on the other hand, each person received a daily wage of two pints (2 ℓ) of grain, which amounted to six pecks (62 ℓ) over a month. Since Mao expected the transport of provisions to continue for 280 days, the total annual wage in kind totaled fifty-six pecks (580 ℓ) of grain. When compared to the forty-two pecks of grain that the carters could have purchased with their wages, the economic advantage of his method appeared obvious to Mao. "In my humble opinion," asserted Mao, "the people of the Liao region will willingly come forward."[67]

Finally, perhaps reflecting his concern that such an economic argument alone might not be sufficiently compelling, Mao highlighted the adaptability of the human body to a wide range of working and climatic conditions. "Humans differ from carts or oxen," noted Mao, "in that they can work shifts, and that we are able to rotate them. They can work throughout the year without interruption, stopped only by heavy rain or snow. Such days [of heavy rain or snow] do not exceed thirty days a year."[68] For officials in the Ming civil and military administration, such a line of argument likely proved most effective as their performance was subject to constant scrutiny by peers and censorial officials. In Mao's view, not only could humans carry heavy loads and walk long distances at a relatively low cost, they could also provide crucial reliability for military transport under testing conditions. As Mao pointed out earlier in the essay, carts could break down, and pack animals could collapse while transporting provisions. In stark contrast, according to Mao, the human body had proven remarkably resilient. Admittedly, the same humans could also commit fraud by swapping sacks. Mao must have reasoned, however, that the overall majority of the bearers were obedient and dutiful. Curiously left out of his argument is the likelihood that humans could also collapse while transporting provisions, succumbing to illnesses, injuries, or exhaustion. If Mao considered the fragility of the human body, he in the end chose not to address the matter in his writings. As we come to the closing passages of Mao's essay on human transport in *Daring to Speak*, we cannot help but wonder about the human toll of his method of transporting provisions in wartime Liaodong in the early seventeenth century, and about the intriguing interplay between technology, efficiency, and reliability in the mind of the erudite late Ming scholar.

Acknowledgements

Earlier versions of this article were presented at seminars and workshops at the Max Planck Institute for the History of Science, Ruhr-Universität Bochum, Georg-August-Universität Göttingen, the University of British Columbia, and the University of Oxford. I am grateful to all the participants for their invaluable feedback. My sincere thanks to Julia Schneider, Charlotte Backerra, Francesca Bray, Ihor Pidhainy, and the anonymous reviewers for their insightful comments. Nung-yao Lin generously offered help with preparing the map. I would like to especially thank Dagmar Schäfer for her support for this project.

Disclosure Statement

No potential conflict of interest was reported by the author.

Endnotes

1 See, for example, Franke and Liew-Herres, *Sources of Ming History*, 619–744. For studies of late Ming military logistics, see my dissertation, "Provisions and Profits in a Wartime Borderland," as well as my article, "War, Supply Lines, and Society," 109–152. For analysis of late Ming maritime networks and transport in the Bohai Sea, see Liu, "Beyond the Land"; Hong, "Ming Dynasty Maritime Provisions Transport."

2 *Sadae mun'gwe* 事大文軌 (Exemplars of Serving the Great State), *kwŏn* 卷 3, Wanli21/1/? (2/?/1593), in *Imjinwaeran saryo ch'ongsŏ:*

Taemyŏng oegyo p'yŏn 壬辰倭亂史料叢書: 對明外交篇 (Collectanea of Historical Sources on the Imjin War: Diplomatic Relations with the Ming), ed. Han Myŏnggi 韓明基 and Yi Sanghun 李相薰 (Chinju: Kungnip chinju pangmulgwan, 2003), 1:38. Conversions of Chinese weights and measures are based on Qiu Guangming 丘光明, Qiu Long 邱隆, and Yang Ping 楊平, *Zhongguo kexue jishushi: Duliangheng juan* 中國科學技術史: 度量衡卷 (History of Chinese Science and Technology: Weights and Measures) (Beijing: Kexue chubanshe, 2001), 405–417, 447. The translations of Chinese units follow the ones provided in Wilkinson, *New Manual*, 612.

3 *Sŏnjo sillok* 宣祖實錄 (Annals of King Sŏnjo), *kwŏn* 35, Sŏnjo26/2/19 (3/21/1593), in *Chosŏn wangjo sillok* 朝鮮王朝實錄 (Annals of the Chosŏn Dynasty) (1955–59; repr., Seoul: Kuksa p'yŏnch'an wiwŏnhoe, 1968–71), 21:637. Also see An Kyehyŏn 安啓賢, "Chosŏn chŏn'gi-ŭi sŭnggun" 朝鮮前期의 僧軍 (Monk-Soldiers in the Early Chosŏn Period), *Tongbang hakchi* 東方學志 13 (1972): 61; Kim, "The Korean Monk-Soldiers in the Imjin Wars," 91.

4 Goodrich and Fang, eds., *Dictionary of Ming Biography*, 1053–1054; Hummel, ed., *Eminent Chinese of the Ch'ing Period*, 670–672. For Sun Chengzong's political standing and military strategies against the Jurchen, see Swope, *The Military Collapse of China's Ming Dynasty*, 45–63, 85–86.

5 Although Mao presented the *Wubeizhi* to the Chongzhen emperor in 1628, the *Wubeizhi* was first printed in 1621. See Zhao Na 趙娜, "Mao Yuanyi 'Wubeizhi' yanjiu" 茅元儀《武備志》研究 (Study of Mao Yuanyi's *Wubeizhi*) (PhD diss., Huazhong shifan daxue, 2013), 41. For an annotated bibliography of Mao's works, see Ren Daobin 任道斌, ed., *Fang Yizhi zhushu zhijianlu* 方以智著述知見錄 (Selected Bibliography of the Works of Fang Yizhi); *Mao Yuanyi zhushu zhijianlu* 茅元儀著述知見錄 (Selected Bibliography of the Works of Mao Yuanyi) (Beijing: Shumu wenxian chubanshe, 1985), 77–99.

6 Wang Ji 汪楫 et al., comps., *Chongzhen changbian* 崇禎長編 (Long Draft of the History of the Chongzhen Reign), *juan* 卷 7, Chongzhen1/3/25 (4/28/1628), in vol. 6 of *Ming shilu fulu* 明實錄附錄 (Supplements to the *Veritable Records of the Ming*) (Taipei: Zhongyang yanjiuyuan, Lishi yuyan yanjiusuo, 1967), 381. This entry in the *Chongzhen changbian* notes that Mao's *Wubeizhi* consisted of 340 *juan* rather than 240. For bibliographical notes on the *Chongzhen changbian*, see Franke and Liew-Herres, *Sources of Ming History*, 119; Struve, *The Ming-Qing Conflict*, 331.

7 Joseph Needham et al., *Science and Civilisation in China*, vol. 5, *Chemistry and Chemical Technology*, pt. 7, *Military Technology; The Gunpowder Epic* (Cambridge: Cambridge University Press, 1986), 34.

8 Joseph Needham, with the collaboration of Wang Ling, *Science and Civilisation in China*, vol. 4, *Physics and Physical Technology*, pt. 2, *Mechanical Engineering* (Cambridge: Cambridge University Press, 1965), 262. Kenneth Pomeranz cites the efficiency of Chinese stoves as an indication that technological sophistication in China was likely comparable to that in Europe at the beginning of the eighteenth century. See Pomeranz, *The Great Divergence*, 46.

9 A succinct overview of the debate is provided in Little, *New Contributions to the Philosophy of History*, 171–194.

10 Huang, *The Peasant Family and Rural Development*, 317.

11 Pomeranz, *The Great Divergence*, 13.

12 For an analysis of the monetization of military labor in Ming China, see Robinson, "Military Labor in China, c. 1500," 43–80. Also see Moll-Murata, "Tributary Labour Relations in China," 27–48.

13 Here Mao cites a passage from the biography of Han Xin 韓信 in Sima Qian's *Records of the Grand Historian* (*Shiji* 史記), among other texts. The translation follows that of Watson, trans., *Records of the Grand Historian of China*, 214.

14 Mao Yuanyi 茅元儀, *Wubeizhi* 武備志 (Records of Military Preparedness), *juan* 135, in *Zhongguo bingshu jicheng* 中國兵書集成 (Collectanea of Chinese Military Treatises) (Beijing: Jiefangjun chubanshe; Shenyang: Liaoshen shushe, 1989), 32:5683. For bibliographical notes on the *Wubeizhi*, see Franke and Liew-Herres, *Sources of Ming History*, 636–637.

15 Mao, *Wubeizhi, juan* 135, 32:5688. This passage, *sanshi wunong er yishi jiangwu* 三時務農，而一時講武, is found in the "Zhouyu" 周語 (Discourses of the State of Zhou) section of the *Guoyu* 國語 (Discourses of the States). On the passage in question, Wei Zhao 韋昭 (204–273), a scholar of the Three Kingdoms period, commented: "Three seasons are spring, summer, and autumn. One season is winter." See *Guoyu* 國語 (Discourses of the States), *juan* 1, "Zhouyu shang" 周語上 (Discourses of the State of Zhou, pt. 1), in vol. 15 of *Sibu congkan chubian* 四部叢刊初編 (Collectanea of the Four Branches of Literature, First Series), *suoben* 縮本 (Reduced-size edition) (1919–22; repr., Shanghai: Shangwu yinshuguan, 1936), 7.

16 Mao, *Wubeizhi, juan* 136, 32:5713–5714. Sabatino de Ursis's Chinese name was Xiong Sanba 熊三拔. See Goodrich and Fang, *Dictionary of Ming Biography*, 1331–1332. *Taixi shuifa* is in vol. 9 of *Xu Guangqi zhu yi ji* 徐光啓著譯集 (Collected Works and Translations of Xu Guangqi) and in vol. 5 of *Xu Guangqi quanji* 徐光啓全集 (Complete Works of Xu Guangqi), ed. Zhu Weizheng 朱維錚 and Li Tiangang 李天綱, 277–374. *Taixi shuifa* was also included in Xu's *Nongzheng quanshu* 農政全書 (Complete Treatise on Agricultural Administration), which was printed posthumously in 1639.

17 Mao, *Wubeizhi, juan* 138, 32:5827.

18 Bray, *Science and Civilisation in China*, 61; Amano Motonosuke 天野元之助, *Chūgoku konōsho kō* 中國古農書考 (Study of Ancient Chinese Agricultural Treatises) (Tokyo: Ryūkei shosha, 1975), 153–154.

19 Mao, *Wubeizhi, juan* 135, 32:5683–5684.

20 Goodrich and Fang, *Dictionary of Ming Biography*, 1107. For bibliographical notes on Pan's treatise on flood prevention, *Hefang yilan* 河防一覽 (General View of the Control of the Yellow River) (1590), see Franke and Liew-Herres, *Sources of Ming History*, 762.

21 Mao, *Wubeizhi, juan* 140, 32:5925–5927.

22 For bibliographical notes on Luo Hongxian's 羅洪先 *Guangyutu* 廣輿圖 (Enlarged Maps of the Realm) (1557), see Franke and Liew-Herres, *Sources of Ming History*, 751. For a biography of Luo, see Goodrich and Fang, *Dictionary of Ming Biography*, 980–984.

23 The late Ming scholar Wang Zaijin 王在晉 (1564–1643) wrote that the Sancha River, which was connected to the Liao River upstream, sat at the "throat of both east and west at the heart of the entire Liaodong region." Wang Zaijin, *Sanchao liaoshi shilu* 三朝遼事實録 (Annalistic Records of the Affairs in the Liao Region during the Three Reigns of Wanli, Taichang, and Tianqi) (1638), *Zonglüe* 總略 (Summary), in vol. 1 of *Kaiguo shiliao* 開國史料 (Historical Sources on the Founding of the Qing), pt. 3, *Qingshi ziliao* 清史資料 (Sources of Qing History), *di* 第 3 *ji* 輯 (3rd series) (Taipei: Tailian guofeng chubanshe, 1970), 148.

24 Mao, *Wubeizhi, juan* 141, 32:5929–5943.

25 Since the *Yuditu* 輿地圖 (Maps of the Realm) compiled by Zhu Siben 朱思本

only survives in revised and enlarged form in Luo Hongxian's *Guangyutu*, it is difficult to determine whether Luo reproduced or added the section on sea transport accompanied by two maps of sea lanes. The text in this section contains a reference to the thirtieth year of the Hongwu 洪武 reign (1397), and Luo likely authored at least a portion of the text.

26 For a list of route books printed during the Ming-Qing period, see Timothy Brook, *Geographical Sources of Ming-Qing History*, 3–27.

27 Mao, *Wubeizhi, juan* 141, 32:5948. I am grateful to Michael Stanley-Baker for his suggestions about translating this passage.

28 Song's familiarity with the conditions and boats of south China is discussed in Schäfer, *The Crafting of the 10,000 Things*, 50.

29 Song Yingxing 宋應星, *Tiangong kaiwu* 天工開物 (Exploitation of the Works of Nature) (1637) (Beijing: Zhonghua shuju, 1959), 2:43. An English translation is provided in *T'ien-kung k'ai-wu: Chinese Technology in the Seventeenth Century*, trans. E-tu Zen Sun and Sun Shiou-chuan (University Park: Pennsylvania State University Press, 1966), 185. Translation modified.

30 Song Yingxing noted that the use of ox-carts was particularly widespread in today's Shanxi province. Song, *Tiangong kaiwu*, 2:41.

31 Mao, *Wubeizhi, juan* 141, 32:5948.

32 Qi Jiguang 戚繼光, *Lianbing shiji* 練兵實紀 (Practical Account of Military Drill), *Zaji* 雜集 (Miscellaneous Works), in vol. 19 of *Zhongguo bingshu jicheng* (Beijing: Jiefangjun chubanshe; Shenyang: Liaoshen shushe, 1994), *juan* 6, 737; Mao, *Wubeizhi, juan* 141, 32:5948.

33 Mao Yuanyi refers here to a passage in the *Xici* 繫辭 commentary (Commentary on the Appended Phrases) of the *Yijing* 易經 (Classic of Changes). See Lynn, trans., *The Classic of Changes*, 79.

34 Mao, *Wubeizhi, juan* 141, 32:5954. Emmett Essin cites in his study of mules in the US army a manual of pack transportation published in 1917 and writes that "mules loaded with two hundred pounds (91 kg) of supplies could travel twenty-five miles (40 km) a day at a pace of eight miles per hour (13 km/h) for seven consecutive days." See Essin, *Shavetails and Bell Sharps*, 106. Donkeys' lower level of performance compared to horses and mules is also noted in Vaclav Smil's study of energy in traditional agriculture. Typical draft for animals is largely determined as a percentage of their body weight, and for horses Smil provides a figure of 15%. Typical draft for horses is in the range of 50–80 kg, for mules in the range of 50–60 kg, for oxen in the range of 40–70 kg, and for donkeys in the range of 15–30 kg, or about 30 percent of a horse's typical draft. See Smil, *Energy in World History*, 86. For the role of horsepower in American industrialization, also see Greene, *Horses at Work*.

35 Tani Mitsutaka 谷光隆, *Mindai basei no kenkyū* 明代馬政の研究 (Study of Horse Administration in the Ming Period) (Kyoto: Tōyōshi kenkyūkai, Kyoto University, 1972), 180–181. According to Essin's analysis of the use of horses and mules in the American Civil War, "[e]ach horse required fourteen pounds (6.4 kg) of hay and twelve pounds (5.4 kg) of grain, while mules needed the same amount of hay and nine pounds (4.1 kg) of oats, corn, or barley." See Essin, *Shavetails and Bell Sharps*, 72.

36 Mao, *Wubeizhi, juan* 141, 32:5954.

37 Ibid., 5955.

38 *Haiyun zhaichao* 海運摘鈔 (Selected Memorials on Sea Transport), *juan* 2, in vol. 4 of *Ming-Qing shiliao congshu bazhong* 明清史料叢書八種 (Eight Collectanea of Historical Materials of the Ming-Qing Period) (Beijing: Beijing tushuguan chubanshe,

2005), 352. This memorial was submitted by Li Changgeng 李長庚 (d. 1644), who at the time held the positions of Right Vice Minister (*youshilang* 右侍郎) of Revenue and Assistant Censor-in-Chief (*qianduyushi* 僉都御史). In 1619, Zhou Yongchun 周永春 held the position of Governor (*xunfu* 巡撫) of Liaodong. Xu Guangqi also commented that one camel was capable of carrying out the work of two oxen but only ate as much as an ox. See Xu Guangqi, "Yang tuo" 養駝 (Nurturing Camels), in *Nongshu caogao* 農書草稿 (Drafts of an Agricultural Treatise), which is included in vol. 11 of *Xu Guangqi zhu yi ji* and in vol. 5 of *Xu Guangqi quanji*, 460.

39 Mao, *Wubeizhi, juan* 141, 32:5955.

40 *Yuanshi* 元史 (Standard History of the Yuan Dynasty), comps. Song Lian 宋濂 et al. (Beijing: Zhonghua shuju, 1976), *juan* 188, 14:4304–4605. This passage uses the word *mi* 米 (husked grain) in describing Dong Tuanxiao's method of human transport. For examples of ratios of husked to unhusked grains, see Chemla and Ma, "How Do the Earliest Known Mathematical Writings Highlight the State's Management of Grains in Early Imperial China?" Also see Wilkinson, *New Manual*, 618. I am grateful to Karine Chemla for directing my attention to early Chinese mathematical texts.

41 *Yuanshi, juan* 188, 14:4304–4305; Mao, *Wubeizhi, juan* 141, 32:5955. For Dong's role in the Yuan defenses in the Huai-Hai region, see Robinson, *Empire's Twilight*, n. 101–102, 326.

42 Mao Yuanyi, "Yu Zhou Huxi huyuan lun renyun shu" 與周澥西户垣論人運書 (Letter to Zhou Huxi on the Matter of Human Transport), *Huomou* 藿謀 (Coarse Deliberation), *juan* 6, in *Shimin weichuji* 石民未出集 (Collected Works of Mao Yuanyi before Entering Officialdom), in vol. 73 of *Siku jinhuishu congkan bubian* 四庫禁燬書叢刊補編 (Supplement to the *Collectanea of Banned and Destroyed Books*) (Beijing: Beijing chubanshe, 2005), 73:601–603. Shimin 石民 was one of Mao Yuanyi's literary names.

43 Mao, *Wubeizhi, juan* 141, 32:5956. Here Mao offers the approximate weight of a sack of four pecks of husked grain, noting its weight should not exceed fifty catties. In discussing the transport of provisions, Chinese and Korean sources normally explain the size of loads in terms of volume, not in terms of weight. If we base our calculations on the figures provided by Mao and divide fifty catties by four pecks, then we arrive at an approximate average weight of twelve and a half catties (7.5 kg), corresponding to a load of one peck (10 ℓ). At this ratio, a load of one bushel (104 ℓ) would have weighed 125 catties (75 kg). The Song scholar Shen Gua (or Kuo) 沈括 (1031-1095) noted in *Mengxi bitan* 夢溪筆談 (Brush Talks from a Dream Brook) that "the weight of one bushel (*hu* 斛) of polished round-grained rice (*jingmi* 粳米) is taken today as the equivalent of one picul (*shi* 石). The practice is to reckon one picul as 92.5 catties (*jin* 斤). Shen Gua, *Mengxi bitan* (Yangzhou: Jiangsu Guangling guji keyinshe, 1997), *shang* 上 (vol. 1), *juan* 3, 1. This passage is cited in Mao, *Wubeizhi, juan* 84, 30:3272 and in Tang Shunzhi 唐順之, *Wubian* 武編 (Military Compendium), in vol. 13 of *Zhongguo bingshu jicheng, qianji* 前集 (pt. 1), *juan* 5, 753. Translation modified from Wilkinson, *New Manual*, 617.

44 In the *Wubeizhi*, Mao used circles, water-drop-shaped marks, underlining, and dots to emphasize many of his passages. They are explained in the legend in Mao, *Wubeizhi*, 27:91.

45 Mao, *Wubeizhi, juan* 141, 32: 5956. 8 pecks (4 pecks × 2) × 1000 laps (500 laps × 2) × 5 (180 men ÷ 36 men) = 4,000 bushels.

46 *Sadae mun'gwe, kwŏn* 3, Wanli21/1/? (2/?/1593), 1:38.

47 Mao, *Wubeizhi, juan*. 141, 32:5956. If 180 bearers and three cooks are assigned to every *li*, the total number of bearers and cooks needed to cover the distance of 100 *li* would be 18,300. It remains unclear why Mao added four more persons to the total.
48 Mao, *Wubeizhi, juan* 141, 32:5956.
49 For an overview of the Battle of Sarhu, see Wakeman, *The Great Enterprise*, 62–63.
50 Mao Yuanyi, *Maoyan xu* 冒言序 (Preface to *Daring to Speak*), in *Shimin weichuji*, 73:672.
51 For Mao's planning and writing of the *Wubeizhi*, see Zhao, "Mao Yuanyi '*Wubeizhi*' yanjiu," 42. In a letter to Gu Jiuchou dated 1619, Mao wrote that the *Wubeizhi* was a culmination of his work over the previous fifteen years. But the actual writing of the *Wubeizhi* appears to have taken about three years. See Mao Yuanyi, "Yu Gu Jiuchou shuchang shu, jiwei" 與顧九疇庶常書 己未 (Letter to Gu Jiuchou, 1619), *Huomou, juan* 3, in *Shimin weichuji*, 73:577–578.
52 Mao Yuanyi, "Renyun" 人運 (Human Transport), *Maoyan* 冒言 (Daring to Speak), *juan* 1, in *Shimin weichuji*, 73:677–678. *Maoyan* is also included in *Shimin sishi ji* 石民四十集 (Collected Works of Mao Yuanyi at Age Forty), in vol. 109 of the *Ji* 集 (Belles-Lettres) Branch of *Siku jinhuishu congkan* 四庫禁毀書叢刊 (Collectanea of Banned and Destroyed Books), *juan* 7–9, 62–86.
53 In the *Wubeizhi*, Mao Yuanyi noted that Gaizhou Guard was located 240 *li*, Fuzhou Guard 420 *li*, and Jinzhou Guard 600 *li* south of Liaoyang. Although Mao does not further specify the area which should fall within the range of a total of 450 *li*, he possibly sought to transport provisions from Fuzhou Guard to Liaoyang. The Jurchen captured Shenyang and Liaoyang in 1621. See Mao, *Wubeizhi, juan* 189, 35:8065.
54 Mao, "Renyun," 73:677–678. According to the *Collected Statutes of the Great Ming* (*Da Ming Huidian* 大明會典), the General Administration Circuit (*Fenshou dao* 分守道) and the General Surveillance Circuit (*Fenxun dao* 分巡道) of Liaodong were both called Liaohai Dongning 遼海東寧 with separate jurisdictions. Dongning and Liaohai Circuits here possibly refer to the General Surveillance and General Administration Circuits, respectively.
55 Liaohai 遼海 Circuit here likely referred to the General Administration Circuit of Liaohai Dongning (*Fenshou Liaohai Dongning dao* 分守遼海東寧道), which administered Liaoyang 遼陽, Shenyang 瀋陽, Fushun 撫順, Puhe 蒲河, among other areas. Hai-Gai 海盖, or Jin-Fu Hai-Gai 金復海盖, Circuit referred to the Military Defense Circuit (*Bingbei dao* 兵備道) which administered the four Guards of Jinzhou 金州, Fuzhou 復州, Haizhou 海州, and Gaizhou 盖州 on the Liaodong peninsula, among other areas.
56 Mao, "Renyun," 73:677–678.
57 Mao, "Renyun," 73:678. Although Mao gave the figure of 367,540 bushels as the total volume of husked grain needed for the bearers' wages, the figure should have been 367,740. If each person received two pints of grain a day, 180 laborers assigned to every *li* received a total daily payment of three bushels and six pecks of grain. Multiplied by the distance (450 *li*) and the number of days (227 days), the total figure would be 367,740, not 367,540.
58 Mao, "Renyun," 73:678. Mao here used the word *su* 粟, which could also mean unhusked grain.
59 Mao, "Renyun," 73:678.
60 Ibid.
61 For the establishment of Kuandian 寬奠 and Aiyang 靄陽 Forts and other military outposts near the Yalu River during the Ming, see Wada Sei 和田清, "Min-matsu ni okeru Ōryokukō hōmen no kaitaku" 明末に於ける鴨綠江方面の開拓 (Development of the

Area along the Yalu River in the Late Ming Period), *Shigaku zasshi* 史學雜誌 30 (1919): 937–962, 1051–1078, 1156–1168, 1250–1273.

62 Kim Sŏkchu 金錫胄, "Kangbyŏn kyewŏn changhyŏkp'a saŭi" 江邊繼援將革罷事議 (Proposal to Abolish the Posts of Supporting Commanders in the Area along the Amnok/Yalu River), *Sŏgam yugo* 息庵遺稿 (Posthumous Manuscripts of Kim Sŏkchu), *kwŏn* 17, in vol. 145 of *Yŏngin p'yojŏm Han'guk munjip ch'onggan* 影印標點韓國文集叢刊 (Photofacsimile, Punctuated Reprint of Collected Works of Korea) (Seoul: Minjok munhwa ch'ujinhoe, 1995), 418.

63 Mao, "Renyun," 73:678.

64 Ibid.

65 In his letter to Zhou Huxi, Mao wrote that of the 100,000 soldiers stationed in Guangning 廣寧, 40,000 were to be deployed for combat, and 30,000 could be assigned to transport duties. He suggested that the city could be defended with the remaining 30,000 soldiers. See Mao, "Yu Zhou Huxi huyuan lun renyun shu," *Huomou, juan* 6, in *Shimin weichuji*, 73:601.

66 Mao, "Renyun," 73:678.

67 Ibid.

68 Ibid.

Bibliography

Primary Sources

Chongzhen changbian 崇禎長編 (Long Draft of the History of the Chongzhen Reign). In Vols. 6–14 of *Ming shilu fulu* 明實錄附錄 (Supplements to the *Veritable Records of the Ming*). Taipei: Zhongyang yanjiuyuan, Lishi yuyan yanjiusuo, 1967.

Guoyu 國語 (Discourses of the States). In Vol. 15 of *Sibu congkan chubian* 四部叢刊初編 (Collectanea of the Four Branches of Literature, First Series). *Suoben* 縮本 (Reduced-size edition). 1919–1922. Reprint, Shanghai: Shangwu yinshuguan, 1936.

Haiyun zhaichao 海運摘鈔 (Selected Memorials on Sea Transport). In Vol. 4 of *Ming-Qing shiliao congshu bazhong* 明清史料叢書八種 (Eight Collectanea of Historical Materials of the Ming-Qing Period). Beijing: Beijing tushuguan chubanshe, 2005.

Kim, Sŏkchu 金錫胄. "Kangbyŏn kyewŏn changhyŏkp'a saŭi" 江邊繼援將革罷事議 (Proposal to Abolish the Posts of Supporting Commanders in the Area along the Amnok/Yalu River). *Sŏgam yugo* 息庵遺稿 (Posthumous Manuscripts of Kim Sŏkchu). In Vol. 145 of *Yŏngin p'yojŏm Han'guk munjip ch'onggan* 影印標點韓國文集叢刊 (Photofacsimile, Punctuated Reprint of Collected Works of Korea). Seoul: Minjok munhwa ch'ujinhoe, 1995.

Mao, Yuanyi 茅元儀. *Wubeizhi* 武備志 (Records of Military Preparedness). Vols. 27–36 of *Zhongguo bingshu jicheng* 中國兵書集成 (Collectanea of Chinese Military Treatises). Beijing: Jiefangjun chubanshe; Shenyang: Liaoshen shushe, 1989.

Mao, Yuanyi. *Huomou* 藿謀 (Coarse Deliberation). In *Shimin weichuji* 石民未出集 (Collected Works of Mao Yuanyi before Entering Officialdom). In Vol. 73 of *Siku jinhuishu congkan bubian* 四庫禁燬書叢刊補編 (Supplement to the *Collectanea of Banned and Destroyed Books*), 549–670. Beijing: Beijing chubanshe, 2005.

Mao, Yuanyi. *Maoyan* 冒言 (Daring to Speak). In *Shimin weichuji*. In Vol. 73 of *Siku jinhuishu congkan bubian*, 671–700. Beijing: Beijing chubanshe, 2005.

Mao, Yuanyi. *Shimin sishi ji* 石民四十集 (Collected Works of Mao Yuanyi at Age Forty). In Vol. 109–110 of the *Ji* 集 (Belles-Lettres) Branch of *Siku jinhuishu congkan* 四庫禁毀書叢刊 (Collectanea of Banned and Destroyed Books). Beijing: Beijing chubanshe, 2000.

Qi, Jiguang 戚繼光. *Lianbing shiji* 練兵實紀 (Practical Account of Military Drill). Vol. 19 of *Zhongguo bingshu jicheng*. Beijing: Jiefangjun chubanshe; Shenyang: Liaoshen shushe, 1994.

Sadae mun'gwe 事大文軌 (Exemplars of Serving the Great State). In *Imjinwaeran saryo ch'ongsŏ: Taemyŏng oegyo p'yŏn* 壬辰倭亂史料叢書: 對明外交篇 (Collectanea of Historical Sources on the Imjin War: Diplomatic Relations with the Ming), edited by Han Myŏnggi 韓明基 and Yi Sanghun 李相薰. 11 vols. Chinju: Kungnip chinju pangmulgwan, 2003.

Shen, Gua (Kuo) 沈括. *Mengxi bitan* 夢溪筆談 (Brush Talks from a Dream Brook). 2 vols. Yangzhou: Jiangsu Guangling guji keyinshe, 1997.

Song, Lian 宋濂 et al., comps. *Yuanshi* 元史 (Standard History of the Yuan Dynasty). 15 vols. Beijing: Zhonghua shuju, 1976.

Song, Yingxing 宋應星. *Tiangong kaiwu* 天工開物 (Exploitation of the Works of Nature) (1637). 3 vols. Beijing: Zhonghua shuju, 1959.

Sŏnjo sillok 宣祖實錄 (Annals of King Sŏnjo). In *Chosŏn wangjo sillok* 朝鮮王朝實錄 (Annals of the Chosŏn Dynasty). 1955–1959. Reprint, Seoul: Kuksa p'yŏnch'an wiwŏnhoe, 1968–1971.

Tang, Shunzhi 唐順之. *Wubian* 武編 (Military Compendium). Vols. 13–14 of *Zhongguo bingshu jicheng*. Beijing: Jiefangjun chubanshe; Shenyang: Liaoshen shushe, 1989.

Wang, Zaijin 王在晉. *Sanchao liaoshi shilu* 三朝遼事實録 (Annalistic Records of the Affairs in the Liao Region during the Three Reigns of Wanli, Taichang, and Tianqi) (1638). Vols. 1–3 of *Kaiguo shiliao* 開國史料 (Historical Sources on the Founding of the Qing), pt. 3. *Qingshi ziliao* 清史資料 (Sources of Qing History), *di* 第 3 *ji* 輯 (3rd Series). Taipei: Tailian guofeng chubanshe, 1970.

Xu Guangqi zhu yi ji 徐光啟著譯集 (Collected Works and Translations of Xu Guangqi). 20 vols. Shanghai: Shanghai guji chubanshe, 1983.

Zhu, Weizheng 朱維錚, and Li Tiangang 李天綱, eds. *Xu Guangqi quanji* 徐光啓全集 (Complete Works of Xu Guangqi). 10 vols. Shanghai: Shanghai guji chubanshe, 2010.

Secondary Sources

Amano, Motonosuke 天野元之助. *Chūgoku konōsho kō* 中國古農書考 (Study of Ancient Chinese Agricultural Treatises). Tokyo: Ryūkei shosha, 1975.

An, Kyehyŏn 安啓賢. "Chosŏn chŏn'gi-ŭi sŭnggun" 朝鮮前期의 僧軍 (Monk-Soldiers in the Early Chosŏn Period). *Tongbang hakchi* 東方學志 13 (1972): 27–96.

Bray, Francesca. *Science and Civilisation in China*. Vol. 6, *Biology and Biological Technology*. Pt. 2, *Agriculture*, edited by Joseph Needham. Cambridge: Cambridge University Press, 1984.

Brook, Timothy. *Geographical Sources of Ming-Qing History*. 2nd ed. Ann Arbor, MI: Center for Chinese Studies, University of Michigan, 2002.

Chemla, Karine, and Biao Ma. "How Do the Earliest Known Mathematical Writings Highlight the State's Management of Grains in Early Imperial China?" *Archive for History of Exact Sciences* 69, no. 1 (2015): 1–53.

Essin, Emmett M. *Shavetails and Bell Sharps: The History of the U.S. Army Mule*. Lincoln: University of Nebraska Press, 1997.

Franke, Wolfgang. *Annotated Sources of Ming History: Including Southern Ming and Works on Neighbouring Lands, 1368–1661*. Revised and Enlarged by Liew-Herres Foon Ming. 2 vols. Kuala Lumpur: University of Malaya Press, 2011.

Goodrich, L. Carrington, and Chaoying Fang, eds. *Dictionary of Ming Biography, 1368–1644*. 2 vols. New York: Columbia University Press, 1976.

Greene, Ann Norton. *Horses at Work: Harnessing Power in Industrial America*. Cambridge, MA: Harvard University Press, 2008.

Hasegawa, Masato. "Provisions and Profits in a Wartime Borderland: Supply Lines and Society in the Border Region Between China and Korea, 1592–1644." PhD diss., Yale University, 2013.

Hasegawa, Masato. "War, Supply Lines, and Society in the Sino-Korean Borderland of the Late Sixteenth Century." *Late Imperial China* 37, no. 1 (2016): 109–152.
Hong, Sung Ku. "Ming Dynasty Maritime Provisions Transport during the Second Stage of the East Asian War (1597–98)." *Chinese Studies in History* 52, no. 1 (2019): 42–58.
Huang, Philip C. C. *The Peasant Family and Rural Development in the Yangzi Delta, 1350–1988*. Stanford, CA: Stanford University Press, 1990.
Hummel, Arthur W., ed. *Eminent Chinese of the Ch'ing Period*. 2 vols. 1943. Reprint, Taipei: SMC Publishing, 1991.
Kim, Samuel Dukhae. "The Korean Monk-Soldiers in the Imjin Wars: An Analysis of Buddhist Resistance to the Hideyoshi Invasion, 1592–1598." PhD diss., Columbia University, 1978.
Little, Daniel. *New Contributions to the Philosophy of History*. New York: Springer, 2010.
Liu, Jing. "Beyond the Land: Maritime Interactions, Border Control, and Regional Powers Between China and Korea, 1500–1637." PhD diss., Syracuse University, 2019.
Lynn, Richard John, trans. *The Classic of Changes: A New Translation of the I Ching as Interpreted by Wang Bi*. New York: Columbia University Press, 1994.
Moll-Murata, Christine. "Tributary Labour Relations in China During the Ming-Qing Transition (Seventeenth to Eighteenth Centuries)." *International Review of Social History* 61, no. S24 (2016): 27–48.
Needham, Joseph. With the Collaboration of Ho Ping-Yü, Lu Gwei-Djen, and Wang Ling. *Science and Civilisation in China*. Vol. 5, *Chemistry and Chemical Technology*. Pt. 7, *Military Technology; The Gunpowder Epic*. Cambridge: Cambridge University Press, 1986.
Needham, Joseph. With the Collaboration of Wang Ling. *Science and Civilisation in China*. Vol. 4, *Physics and Physical Technology*. Pt. 2, *Mechanical Engineering*. Cambridge: Cambridge University Press, 1965.
Pomeranz, Kenneth. *The Great Divergence: China, Europe, and the Making of the Modern World Economy*. Princeton, NJ: Princeton University Press, 2000.
Qiu, Guangming 丘光明, Qiu Long 邱隆, and Yang Ping 楊平. *Zhongguo kexue jishushi: Duliangheng juan* 中國科學技術史：度量衡卷 (History of Chinese Science and Technology: Weights and Measures). Beijing: Kexue chubanshe, 2001.
Ren, Daobin 任道斌, ed. *Fang Yizhi zhushu zhijianlu* 方以智著述知見錄 (Selected Bibliography of the Works of Fang Yizhi); *Mao Yuanyi zhushu zhijianlu* 茅元儀著述知見錄 (Selected Bibliography of the Works of Mao Yuanyi). Beijing: Shumu wenxian chubanshe, 1985.
Robinson, David M. *Empire's Twilight: Northeast Asia under the Mongols*. Cambridge, MA: Harvard University Asia Center for the Harvard-Yenching Institute, 2009.
Robinson, David M. "Military Labor in China, c. 1500." In *Fighting for a Living: A Comparative History of Military Labor 1500–2000*, edited by Erik-Jan Zürcher, 43–80. Amsterdam: Amsterdam University Press, 2013.
Schäfer, Dagmar. *The Crafting of the 10,000 Things: Knowledge and Technology in Seventeenth-Century China*. Chicago: University of Chicago Press, 2011.
Smil, Vaclav. *Energy in World History*. Boulder: Westview Press, 1994.
Song, Yingxing. *T'ien-kung k'ai-wu: Chinese Technology in the Seventeenth Century*. Translated by E-tu Zen Sun and Shiou-chuan Sun. University Park: Pennsylvania State University Press, 1966.
Struve, Lynn A. *The Ming-Qing Conflict, 1619–1683: A Historiography and Source Guide*. Ann Arbor, MI: Association for Asian Studies, 1998.
Swope, Kenneth M. *The Military Collapse of China's Ming Dynasty, 1618–44*. London: Routledge, 2014.
Tani, Mitsutaka 谷光隆. *Mindai basei no kenkyū* 明代馬政の研究 (Study of Horse Administration in the Ming Period). Kyoto: Tōyōshi kenkyūkai, Kyoto University, 1972.

Wada, Sei 和田清. "Min-matsu ni okeru Ōryokukō hōmen no kaitaku" 明末に於ける鴨綠江方面の開拓 (Development of the Area along the Yalu River in the Late Ming Period). *Shigaku zasshi* 史學雜誌 30 (1919): 937–962, 1051–1078, 1156–1168, 1250–1273.
Wakeman, Frederic, Jr. *The Great Enterprise: The Manchu Reconstruction of Imperial Order in Seventeenth-Century China*. 2 vols. Berkeley: University of California Press, 1985.
Watson, Burton, trans. *Records of the Grand Historian of China: Translated from the Shih chi of Ssu-ma Ch'ien*. 2 vols. New York: Columbia University Press, 1961.
Wilkinson, Endymion. *Chinese History: A New Manual*. 5th ed. Cambridge, MA: Endymion Wilkinson, c/o Harvard University Asia Center, 2018.
Zhao, Na 趙娜. "Mao Yuanyi '*Wubeizhi*' yanjiu" 茅元儀《武備志》研究 (Study of Mao Yuanyi's *Wubeizhi*). PhD diss., Huazhong shifan daxue, 2013.

Notes on Contributor

Masato Hasegawa is a Postdoctoral Fellow at the Max Planck Institute for the History of Science in Berlin, specializing in the history of technology and the environment in late imperial China and Chosŏn Korea. Correspondence to: mhasegawa@mpiwg-berlin.mpg.de