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A methodology for assessing highway logistics applied in the Chinese Communist attack on India.

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TONNAGE THROUGH TIBET

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A more than routine interest has recently been focused on problems of highway logistics by the Communist Chinese threat along the northeastern border of India. The magnitude of this threat depends in large part on the Chinese ability to move military supplies by road from railheads deep in China to the areas of conflict; air transport, the only alternative, is at present not available to the Chinese in significant capacity. It was therefore possible to make an estimate of the threat, in terms of the size of the military forces that could be supplied, by computing the capacity of the roads, setting this against the supply requirements of the forces actually in Tibet, and so determining what excess capacity was available to support additional troops in operations against India. Two other possibly limiting factors had also to be calculated—the number of trucks needed to move the supplies, and the amount of petroleum required to fuel the trucks. The methodology for these calculations, described in the following pages, can be used to estimate the size of military force that can be supported in other campaigns dependent on supply by road.

Roads to the World's Roof

The Chinese forces at the front lines on the Indian border were at the end of roads that wind 700 to 1,800 miles over high and rugged terrain. The three main access routes to Tibet are indicated on the accompanying map. The most important of these is the Tsinghai-Tibet highway running south from Golmo to Lhasa. Golmo can be reached by road either from the railhead in the vicinity of Hsia-tung on the trans-Sinkiang railroad or from that at Hsi-ning west of Lan-chou.

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The major route for the movement of supplies appeared to be the former, from the Hsia-tung area southward through Golmo for about 1,000 miles to An-to or 1,300 miles to Lhasa. The average elevation of this road from Golmo on is about 14,000 feet. Troops along the western border of the North East Frontier Agency, those in the Chumbi Valley opposite Sikkim, and those located as far west as the southern part of Ladakh were supplied by this route.

The other two routes, supplying the extreme flanks, are about equal in importance to each other. The Szechwan-Tibet highway, running west from the railhead at Ch'eng-tu in Szechwan Province, served the troops in the Ch'ang-tu area and the eastern border of NEFA. It goes on from there to Lhasa, a total distance from Ch'eng-tu of about 1,200 miles, over extremely rugged terrain ranging to 12,000 feet in elevation. The third route runs from the railhead in the Urumchi area in northwestern China southwest to Kashgar, then southeast to the Ladakh area. From Urumchi to Rudog it covers about 1,340 miles at elevations ranging from 3,500 feet in the northern portions to between 11,000 and 16,000 feet in the south.

The combined practical forward capacity of these access routes under ideal conditions was figured at 2,000 short tons per day—1,000 tons delivered to Lhasa via Golmo on the Tsinghai-Tibet highway, 500 tons delivered to Ch'ang-tu from Szechwan for the eastern flank, and 500 tons delivered over the Kashgar-Rudog road for the Ladakh front. These main access routes are supplemented by roads leading forward to the frontier and subsidiary east-west and north-south routes to a total of some 7,500 miles.

Development of a Methodology

By the mid-1950's policy makers as well as transportation intelligence specialists had become greatly concerned about the wide divergence in estimates of the capacities of identical transportation routes and facilities published in supposedly definitive U.S. and UK intelligence reports. These estimates were important to policy makers as a basis for determining the

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size of enemy forces that could be deployed and supported in various areas of the world. Without a common understanding of the factors which entered into the calculation of the capacities of the various forms of transportation, however, it had been impossible for the specialists who made the estimates to arrive at reasonably uniform conclusions. The disparities confused and irritated the policy makers.

As a consequence, the Subcommittee on Transportation of the Economic Intelligence Committee, composed of transportation specialists of the U.S. community, undertook a series of studies which led to the formulation of methodologies for estimating the capabilities of railroads, roads, ports, and inland waterways.¹ These were then sent to the [REDACTED] to get its views. After much consultation and exchange of correspondence, working-level agreement on the method for computing railroad capacity was reached in 1960 and on that for computing road capacity in 1961. These methods were subsequently approved by the logistics specialists who provide intelligence support for SHAPE and are now widely used by the intelligence components of NATO countries.

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In the U.S. government the task of estimating road capacities for intelligence purposes is performed primarily by the intelligence components of the Department of Defense. The estimate of 2,000 tons as the capacity of the major supply routes into Tibet was made originally by DOD analysts by these now standard methods and accepted by other components of the intelligence community. The process is described in brief below.

One begins with the ideal capacity of a road of a given type of surface in perfect condition and good weather, straight, and without traffic hindrances. On paved roads 5-ton trucks

¹For a detailed explanation of these methodologies, see Department of the Army Field Manual FM 55-8, *Transportation Intelligence*, December 1961.

are assumed to move at 25 miles per hour spaced 300 feet apart to allow for the "concertina" (compression wave) action inherent in any continuous truck convoy operation. On unpaved roads the dust hazard requires increased spacing and decreased speed. A simple calculation gives the number of trucks that can be moved in both directions during a 24-hour period, considering only the speed, interval between vehicles, and type of surface.

This *basic capacity* is then reduced to obtain what is known as *operational capacity*, which makes allowance for the constraints imposed by driver inefficiency, vehicle casualties, essential maintenance enroute, and unforeseen operational developments. These contingencies are estimated to reduce the basic capacity by 20 percent. A *practical capacity* is obtained by applying further reduction factors to the operational capacity to take into account the following:

Less than ideal road characteristics;

Turning and crossing operations, including delays caused by convoys entering and leaving the highway and the movement across the highway of other essential traffic, civilian and military;

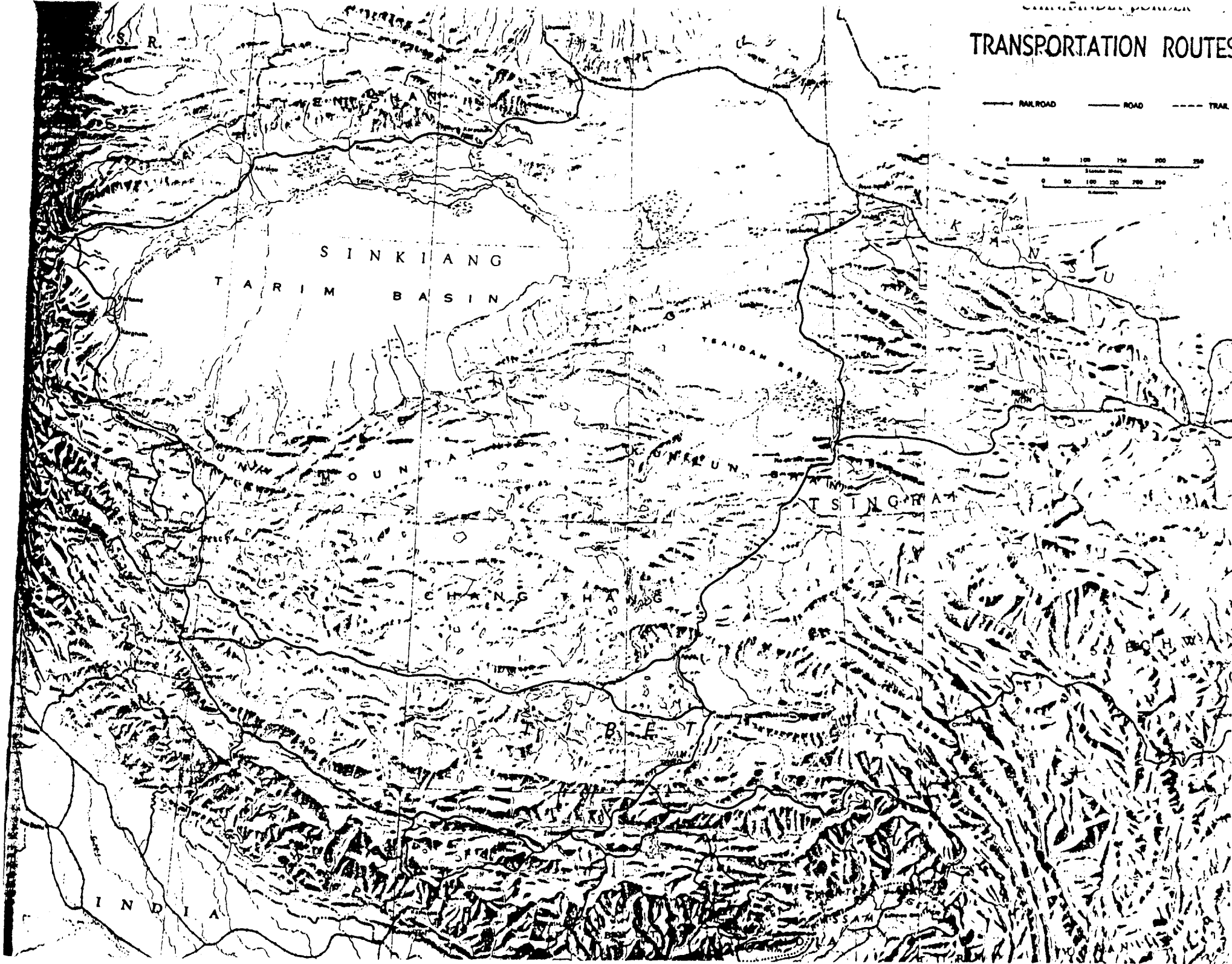
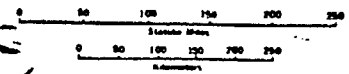
Operational phasing, including the constraints created by administrative and civilian vehicles, stops for meals, refueling, driver rest periods, and the reduced efficiency of night operations.

The resulting practical capacity is expressed in vehicles per day traveling in both directions. Multiplication by the net load per truck, in this case 3 tons, gives the daily tonnage in both directions, and half of this is the practical forward capacity of the road in tons per day.

The value of the several reduction factors has been derived from engineering data on highway transportation and capacity, taking into account vehicle performance and road design, construction, and maintenance. Where precise data were not available on certain types of roads, the experience of highway transport specialists and engineers in truck convoy operations was consulted in assigning values.

TRANSPORTATION ROUTES

RAILROAD ROAD TRAIL



In formula form the calculation looks like this:

$$\begin{aligned}
 B &= 0.8A \\
 C &= B \cdot a \cdot b \cdot c \cdot d \cdot e \cdot f \\
 D &= gC \\
 E &= \frac{D}{2}
 \end{aligned}$$

Where:

- | | | | |
|----|---|----|--|
| A= | basic capacity (vehicles per day) | a= | surface width reduction factor |
| B= | operational capacity (vehicles per day) | b= | shoulder width reduction factor |
| C= | practical capacity (vehicles per day) | c= | curves and gradient factor |
| D= | practical capacity (tons per day) | d= | surface deterioration and maintenance factor |
| E= | practical forward capacity (tons per day) | e= | factor for turning and crossing movements |
| | | f= | operational phasing factor |
| | | g= | load per truck in tons |

Capacity to Tibet

The derivation of the capacity of the Tsinghai-Tibet and Szechwan-Tibet highways will illustrate the application of this methodology. The surface of the Tsinghai-Tibet highway from Golmo to Lhasa is given as crushed rock and gravel with some earth sections. The basic capacity of such a surface is 8,400 and the operational capacity 6,700 5-ton trucks per day. The reduction factors are as follows:

Symbol	Characteristic	Description	Reduction Factor
a	Surface width	30 feet	1.0
b	Shoulder width	Less than 3 feet	0.8
c	Curves and gradient	Over 7 percent	0.6
d	Surface condition	Fair with moist subsoil	0.5
e	Turning and crossing movements		0.85
f	Operational phasing		0.5
g	Load per truck	3 tons	

The practical capacity is then $6,700 \times 1.0 \times 0.8 \times 0.6 \times 0.5 \times 0.85 \times 0.5 = 683$ vehicles, carrying, at an average load of 3 tons, 2,049 tons per day in both directions. Halving this gives a practical forward capacity of 1,025 tons, which may be rounded to 1,000 tons per day.

The surface of the Szechwan-Tibet highway from Ch'eng-tu to Lhasa via Ch'ang-tu is given as crushed rock, gravel, and sand, this also having an operational capacity of 6,700 vehicles per day. But the reduction for surface width and condition is greater:

Symbol	Characteristic	Description	Reduction Factor
a	Surface width	12 to 18 feet	0.6
b	Shoulder width	Less than 3 feet	0.8
c	Curves and gradient	Over 7 percent	0.6
d	Surface condition	Fair to poor, with moist subsoil	0.4
e	Turning and crossing movements		0.85
f	Operational phasing		0.5
g	Load per truck	3 tons	

The practical capacity here is $6,700 \times 0.6 \times 0.8 \times 0.6 \times 0.4 \times 0.85 \times 0.5 = 328$ vehicles or 984 tons per day, 492 tons forward, rounded to 500 tons per day. The capacity of the third route, that from Urumchi, as limited by the mountainous Kashgar-Rudog stretch, was estimated to be the same, 500 tons, as the Szechwan-Tibet highway.

The total capacity of the three access routes would thus be 2,000 tons per day under ideal climatic conditions. On some portions of the roads in Tibet, however, traffic is seasonally stopped by snow, floods, and landslides. A detailed study of weather conditions undertaken by DOD analysts led to the conclusion that they would reduce this capacity, on an average throughout the year, by an additional 20 percent. The net capacity of the access routes thus becomes 1,600 tons daily.

It should be emphasized that the capacity estimate thus derived is for sustained deliveries over at least 90 days. The capacity for a short-term or "crash" movement is much higher, mainly because allowances are not made for maintenance and repair of the roads, under the assumption that they would be permitted to deteriorate in order to avoid interruption of immediate supply operations. How long such a crash movement could be sustained depends on the type of road surface. It was estimated that on the three major access

roads to Tibet four or five times the sustained capacity could be forced through, but only for five days on the Tsinghai-Tibet highway and only for two on the other roads. Then the roads would not be usable for through truck convoys until repaired.

Supply Requirements

The daily resupply requirement for troops in combat and garrison units is the average daily tonnage required to replace expenditures over an extended period. DOD analysts, by considering the normal requirements for the individual units known to be in Tibet, arrived at a total requirement of about 430 short tons per day for the approximately 103,000 Chinese troops fighting there during November 1962. They estimated, for example, that some of the units were organized into infantry divisions (light) at 85 percent of T/O strength, or 14,000 men. In general, such a unit is considered to require 86.4 tons of supplies daily during average combat conditions. Military experts, however, after studying the type of fighting on the Indian border, reduced the estimate of ammunition used from 38.2 to 28.0 tons per division. This made the division's resupply requirement in tons the following:

Class I (Rations)	23.6
Class II and IV (General Supplies)	21.5
Class III (Petroleum Products)	3.1
Class V (Ammunition)	28.0
Total	76.2

On the average, however, the requirements for the forces in Tibet were lower per man than implied in this example. Other troops organized in independent infantry regiments had an estimated requirement for only 22.6 tons per regiment, and border defense regiments required even less. Some troops in garrison were estimated to be using no ammunition.

It is possible that the Chinese had stockpiled considerable amounts of supplies during the summer in anticipation of their fall offensive against India, and the amount transported

to Tibet during November could therefore have been considerably less than 430 tons per day. If, however, the fighting had continued at that level for any length of time, the requirement for road transport would have eventually reached the estimated level.

Vehicle and Fuel Requirements

No coordinated methodology like that for computing the capacity of roads exists for estimating the number of trucks needed to deliver the required supplies nor for computing the fuel requirements of the trucks. Of the several methods used in making such estimates, one which appears to give uniformly good results is described below.²

In order to allow for fuel consumption along the supply route, the route is divided into stages of varying length according to the type of road and terrain, normally about 100 miles each, that can be covered in one day. Fuel consumption for the round trip over each stage is estimated to be 5 percent of the load carried over each, which gives for an average load of 3 short tons about one gallon every 4 miles.³

The requirement for trucks and fuel to operate the supply route is then calculated as follows:

1. The number of loaded trucks on each stage is obtained by dividing the tonnage delivered over it by 3, the average load, and this figure is doubled to include the number returning empty. The sum of these for all the stages is the number of trucks on the road at any given moment.

2. A figure is added for trucks loading at the start and unloading at the end of the road.

³ Five percent of 3 tons is 0.15 tons, or at 323 gallons per ton about 48 gallons for the round trip of 200 miles.

3. Twenty percent is added for trucks temporarily off the road or under repair and for other vehicles in convoy.

4. The delivered tonnage is subtracted from the beginning tonnage to determine the amount of gasoline used en route.⁴

An example of the fuel and tonnage calculation for a 400-mile trip follows:

Beginning of stage 1.	Tonnage of supplies and gasoline loaded	500
Beginning of stage 2.	500 tons minus 5 percent (500 - 25)	475
Beginning of stage 3.	475 tons minus 5 percent (475 - 24)	451
Beginning of stage 4.	451 tons minus 5 percent (451 - 23)	428
Amount of supplies delivered at end of stage 4.	428 tons minus 5 percent (428 - 21)	407*
Tons of gasoline used en route.	(500-407)	93

⁴Another method, used by DOD analysts, which gives approximately the same results is to make a separate calculation for (1) the amount of gasoline used to haul the supplies, (2) the amount of gasoline used to haul the gasoline for the supply trucks, (3) the amount of gasoline used to haul the gasoline used in (2), and so on until the figure becomes insignificant. When the total amount of gasoline required has been obtained, it is added to the tonnage of supplies, and the computation for the number of trucks required is completed.

*If more than a few stages are involved, use of the following formula will greatly facilitate the computation of the tonnage delivered at the end of the final stage.

$$D_n = T(1-.05)^n,$$

where D_n = amount of supplies delivered at end of the n th stage,

n = number of stages,

T = amount of supplies and gasoline loaded at beginning of stage 1, and

$(1-.05)^n$ = 5 percent decrease in load during each stage.

The amount of gasoline required for the round trip of all trucks used in n stages is $T-D_n$.

The corresponding calculation of the number of vehicles required is as follows:

$$\text{Stage 1. } \frac{500}{3} \times 2 = 167 \times 2 = 334$$

$$\text{Stage 2. } \frac{475}{3} \times 2 = 158 \times 2 = 316$$

$$\text{Stage 3. } \frac{451}{3} \times 2 = 150 \times 2 = 300$$

$$\text{Stage 4. } \frac{428}{3} \times 2 = 143 \times 2 = 286$$

Total on road at given moment (sum of above)	1,236
Loading at start	167
Unloading at end	143
Total in use	1,546*
Twenty percent allowance for repairs, off-road, and non-load vehicles	309
Total vehicle park required	1,855

If the supply movement is continued for more than a short period of time, five percent more should be added to the total vehicle park to account for normal vehicle replacement.

Truck and Fuel Availability

Because Communist China is not yet self-sufficient in the production of motor fuel, trucks, and spare parts, both the petroleum industry and motor truck transport being in comparative infancy, this aspect of the logistic problem was given special attention. The extreme length of the supply lines from the railheads to the areas of troop concentration on the Indian border made both the amount of gasoline required and the number of trucks needed of significant proportions; the

*The following formulas can also be used to compute the number of vehicles in use:

$$P = TV_n + \frac{V_1 + V_n}{2}$$

$$V_n = V_1(1-0.05)^{n-1}$$

$$TV_n = V_1 \left(\frac{1-0.95^n}{0.05} \right)$$

where n = number of stages

P = total vehicle park in use

V_1 = number of vehicles used in stage 1 $\left(\frac{\text{starting tonnage}}{\text{tons per vehicle}} \times 2 \right)$

V_n = number of vehicles used in stage n

TV_n = total number of vehicles in use in all n stages

gasoline required to haul supplies 1,300 miles was calculated to be nearly equal to the tonnage delivered. The delivery to the troops of about 430 short tons of supplies daily during November 1962 required about 400 short tons of motor fuel daily and a truck park of about 7,000 vehicles.

It was estimated, however, that the total availability of petroleum products in Communist China in 1962 was about 6.8 million short tons, about 1.4 million of which consisted of motor gasoline. The daily requirement for about 400 tons for the Tibetan front, projected as an annual requirement of about 146,000 tons, would thus be only slightly more than 10 percent of the motor fuel available in 1962. Refineries are located near two of the major access routes: those at Leng-hu, Yu-men, and Lan-chou, not far from the central route to Lhasa, were undoubtedly the source of the gasoline used on that route, and the Tu-shan-tzu refinery near the Karamai oil field in Sinkiang was probably the major source of supply for that used on the route to Ladakh. Thus it appeared that the fuel requirements for the Tibetan fighting were tolerable and the sources of supply convenient. Undoubtedly special military allocations were necessary, however, with resulting cut-backs in other sectors of the economy.

It was estimated that at the end of 1962 the military and civilian truck parks of Communist China each consisted of about 100,000 trucks in operating condition. The size of the civilian truck park is believed to have been reduced from previous years because truck production nearly ceased during 1961 and 1962 and difficulties were experienced in producing or importing spare parts. Present production and imports are about sufficient, however, to maintain the combined park at the 200,000 level. In the military regions of Tibet, Lan-chou, and Sinkiang there were more military trucks available in November 1962 than the estimated 7,000 required to transport military supplies and gasoline. In addition several thousand civilian trucks which are normally employed for economic activities in the provinces of Kansu, Sinkiang, and Tsinghai could have been diverted quickly to the military supply lines if needed.

Leeway for Expanded Operations

The table on the following page was compiled by using the methodologies described above; others broke the daily supply requirement down into that required by troops engaged in combat and that for those not so engaged. It was tentatively concluded in November that military traffic occupied about 20 percent of the capacity of the roads to the front lines from the supply bases in Tibet and about one-third of the combined capacity of the major access routes. It was therefore estimated that the forward roads could support the daily resupply requirement of more than five times the number of troops then in frontline combat units and that the access routes from the railheads could handle more than three times the quantity of supplies then required by the troops located in the whole of Tibet.

More recently it has been estimated that the 105,000 Chinese troops currently in Tibet would have a daily supply requirement of 450 tons during the type of fighting that occurred last November. It has also been estimated that the Chinese may wish to reserve as much as 450 tons per day of the capacity of the roads for support of an air force in Tibet. These requirements, plus an allowance for the trucks that would have to provide petroleum for the operation of the trucks moving supplies, would leave a surplus capacity amounting to about 400 net tons per day that could be used to support additional troops deployed to Tibet. The total ground force strength that could be supported there, according to this estimate, would be on the order of 200,000 men, a maximum of about 15 divisions.

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Tonnage Through Tibet

SUPPLIES REQUIRED BY TROOPS IN TIBET, BY ACCESS ROUTE AND MILITARY DISTRICT

Route and District	Troops	Daily Resupply Requirement				Distance (miles)	Transport Requirements	
		Class I, II & IV (tons)	Class III (tons)	Class V (tons)	Total (tons)		Trucks	Fuel (tons)
Tsinghai-Tibet Highway								
A-li	5,600	17.4	4	9.3	30.7	1,800	821	50
Zhikatsé - Chiang-tzu	17,000	52.7	6	...	58.7	1,500	1,160	70
Shan-nan	13,000	40.2	6	28.0	74.2	1,600	1,608	90
Lhasa	16,000	49.6	10	...	59.6	1,300	988	60
Sub-Total	51,600	159.9	26	37.3	223.2		4,577	270
Szechwan-Tibet Highway								
Ch'ang-tu and Lin-chih	34,000	102.0	11	18.6	131.6	700	1,039	60
Urumchi-Rudog								
Hotien	17,000	52.7	7	18.6	78.3	1,300	1,284	70
Total	102,600	314.6	44	74.5	433.1		6,900	400

' As of 17 November 1962.

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