Infrastructure Preservation:

Extending Road Life in Remote Areas

By Major Robin L. Hagerty, George Mason, and Gil Mason

Recent humanitarian operations in remote areas of Africa and Bosnia have emphasized the need for a strategy to deal with road networks that cannot sustain enough logistics convoy traffic to support military operations. The traditional point of origin for equipment and materiel is a fixed seaport or airfield, with the final distribution point being at the end of an unimproved dirt road. This scenario requires repeated transloading of materiels as route conditions and topography change.

Unimproved secondary roads are commonly built for light- and medium-duty wheel loads, with construction consisting of minimal subgrade preparation overlaid with gravel. Normal maintenance for these roads consists of periodic blading and seasonal applications of new surfacing materials. The subgrade's compaction, strength, and drainage determine the frequency of maintenance needed to keep the road passable.

Initial road failure may be indicated when drivers complain about pot holes, surface rutting, and roughness. Road deterioration that causes vehicle vibration rapidly increases driver fatigue and limits the speed he can safely drive. At the same time, it accelerates vehicle maintenance requirements.

This article describes roadway deterioration caused by military transportation in remote areas and presents some actions that can extend road life.

Discussion

U.S. military relief missions often involve transloading supplies from large transport trucks onto smaller, Army series M923 trucks, which are better suited for use on unimproved roads. The repeated heavy-duty wheel

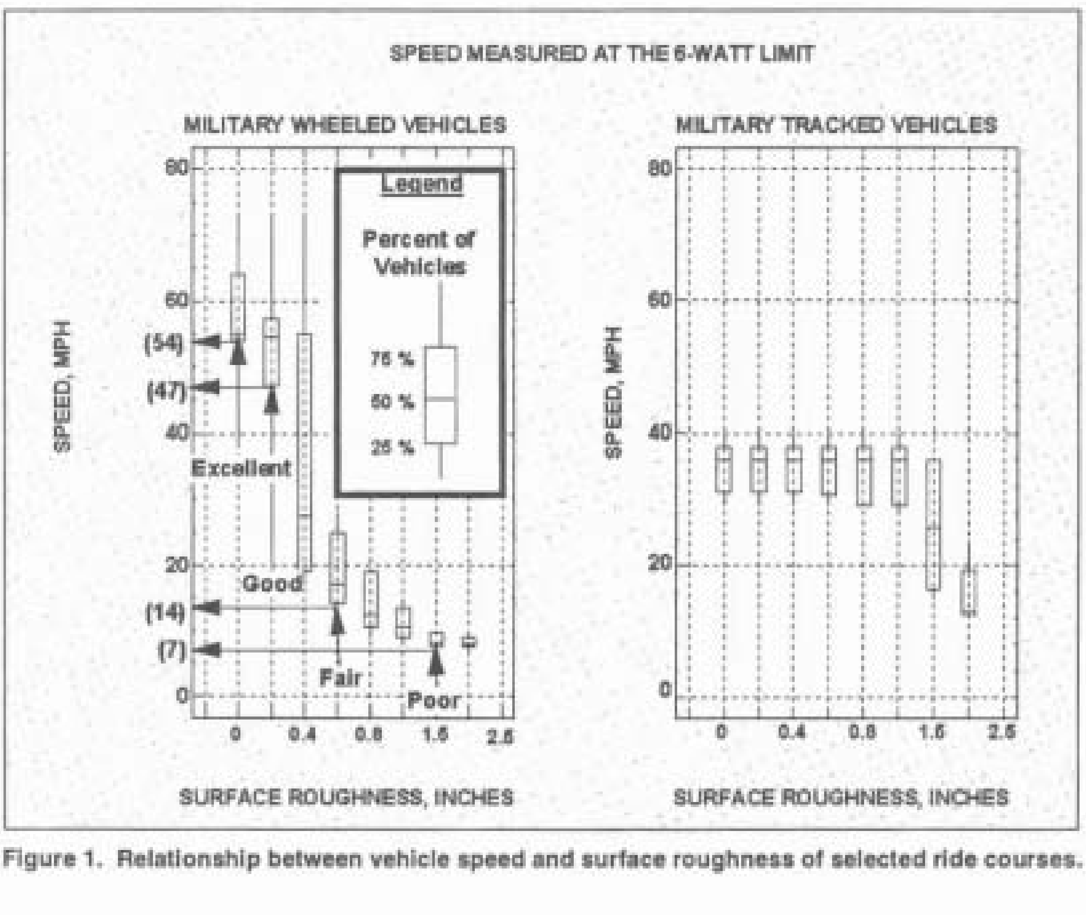

Figure 1. Relationship between vehicle speed and surface roughness of selected ride courses.

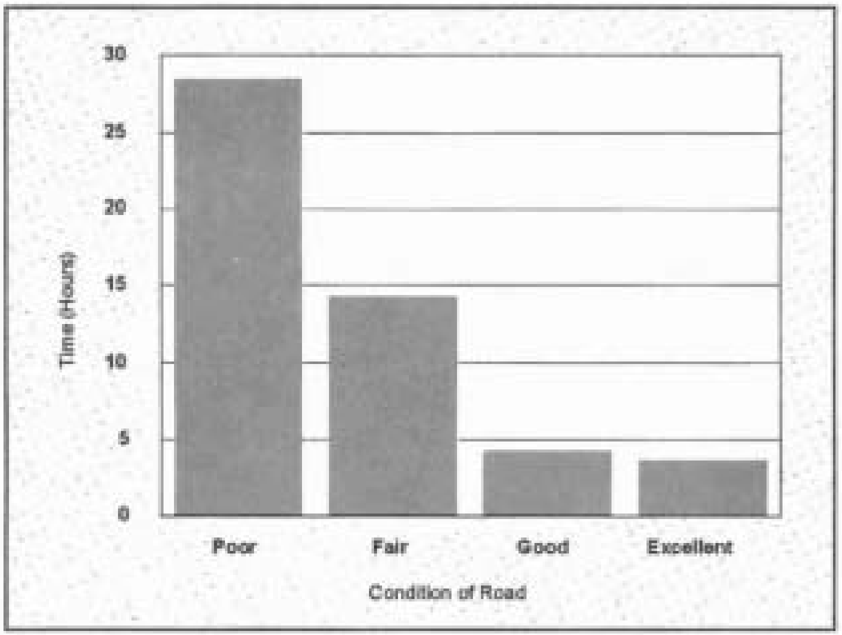

Figure 2. Estimated cargo movement time when speed is limited by road surface roughness.

loads from these trucks' bias-ply tires may immediately or cumulatively affect the roadway until deterioration makes it almost impassable. If tire pressure is high, the tire's ability to absorb many of the dynamic forces imposed by the vehicle traveling along an uneven road surface is limited. Thus, most of the dynamic force is transmitted directly down to the road and up to the driver.

Fatigue Level. The Human Engineering Laboratory at Aberdeen Proving Ground has taken the dynamic forces exerted on the driver over time and translated them into fatigue levels. Several vehicle-testing laboratories built courses to represent various levels of surface roughness existing in different areas of the world. Then military vehicles were driven over these courses, and on-board measurements were recorded. Vertical accelerations at the driver's seat (referred to as absorbed power) were averaged over time and defined in units called *watts*. Further research determined that drivers normally did not operate vehicles for long periods (8 hours or more) at absorbed power levels of 6 watts or more.

Speed. Figure 1 represents the relationship of speed and surface roughness for military wheeled and tracked vehicles tested on various ride courses. The *x* axis in Figure 1 ranges from a very smooth segment of road (no undulations) to an extremely rough segment (approximatley 2.5 inches). Mason, Smith, Gray, and Ahlvin explain in detail this method of describing terrain and road surface roughness. [1]

Using Figure 1 as a means of estimating speed for convoys, four conditions were selected to demonstrate the effects of different levels of roadway deterioration on convoy speed. The average convoy speed is defined at the 1st quartile, or the point where 25 percent of the wheeled military vehicles tested is limited by surface roughness. Thus, a surface roughness of approximately 0 inch, with a corresponding average speed of 54 mph, represents extremely smooth roads in excellent condition. In the next quartile, roads in good condition are represented by a surface roughness of 0.2 inch, with a maximum speed of 47 mph. In the third quartile, a surface roughness of 0.6 inch, with most speeds reduced to 14 mph, represents roads in fair condition. Finally, a surface roughness of 1.5 inches, which may restrict vehicle speed to as low as 7 mph, represents roads in poor condition.

Wheeled vehicles were selected for the study since they normally comprise relief mission convoys. The doctrinal average convoy speed specified in FM 101-10-1, *Organizational, Technical, and Logistical Data*, is 40 km/hr (24.8 mph), which includes halts. The convoy is expected to travel 320 kilometers (198.4 miles) in 8 hours. Excluding time for stops, the vehicles will average speeds of 80 km/hr (49.6 mph). However, visibility, terrain, and road conditions often affect the average speed.

Figure 2 depicts the relationship between the increase in time required to transport supplies and the road condition. Calculations are based on the convoy traveling 200 miles with the speed restricted by the 6-watt fatigue maximum of the driver. Speeds given for the road conditions in Figure 1 are used to calculate the time required to move the payloads in Figure 2.

Soil Stress

Within the parameters of geotechnical engineering, it is convenient to view the subsurface soil stress as a function of stresses from—[2]

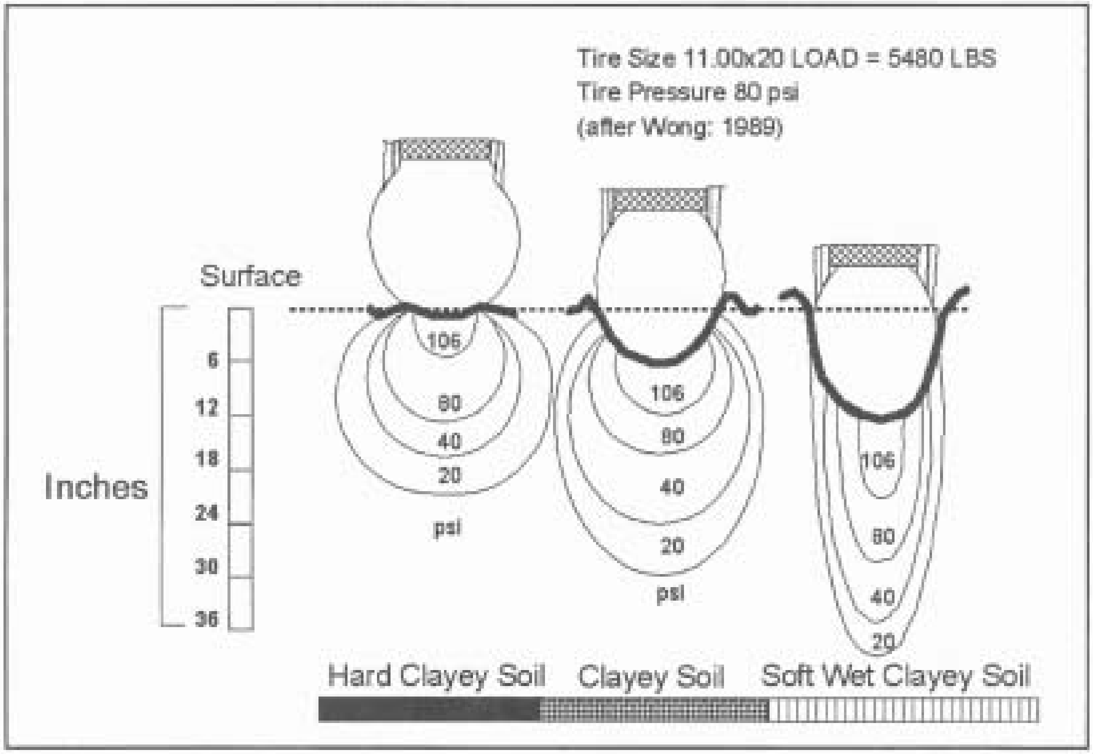

Figure 3. Pressure distribution under a statically loaded tire in various soil types.

- Soil and road surface weight (construction).
- Fluid pressures (weather).
- Externally applied loads (traffic).

Military transporters are primarily concerned with changes in road surface conditions that inhibit movement. Road deterioration normally occurs through interaction of the tire's footprint and the road's ability to absorb and disperse stresses imposed by traffic while maintaining its surface resiliency. Tire design helps the road retain some of its resiliency by absorbing part of the stresses. Without periodic maintenance, the road surface's ability to absorb load stresses is reduced, causing the surface and/or subgrade to fail. As failure continues, the road surface cracks and develops ruts. Rutting begins the chain of events that quickly makes the road difficult to travel at maximum speeds. As traffic accelerates, the deterioration process continues to increase and drivers must reduce speeds to prevent damage to vehicles, the cargo, or themselves.

Figure 3 depicts the distribution of radial stresses from a 5,480-pound tire load in various mediums. It shows the relationships between the passing wheel, its loading effects, rutting, and the dynamics of the passing shock wave as it penetrates the road's subgrade through different soil types.[3] The cross-sectional view shows the downward stresses caused by the wheel as it traverses the road and demonstrates how these stresses are dispersed and absorbed by the subsurface soil.

The figure depicts the shock wave from an M923 cargo truck with bias-ply tires and its cargo centered over the rear wheels. The calculated front-wheel load (worst case) represents the net vehicle weight of 22,515 pounds, combined with its rated gross cargo capacity of 10,000 pounds, and divided by six wheel locations.

Figure 3 shows how different soil types respond to the wheel load but does not specifically identify the stresses caused by vehicle speed. This figure also shows the relationship between soil subsurface strength and the tire's ability to penetrate deeper into the subsurface, thus increasing the severity of rutting with each additional vehicle pass.

Alternatives

Engineers can calculate the effects of wear on unimproved roads; however, many transporters lack a background in using these analytical methods. For field applications, convoy planners need an engineer-developed methodology that is based on scientific principles. It should be easy to understand and simple to apply.

The relationship between a wheel load and its interaction on an unimproved road are predictable. Therefore, the transporter has several alternatives for preserving road life. These include reducing tire pressure, vehicle speed, and vehicle weight.

Reduce Tire Pressure. This action increases the size of the tire footprint and decreases the transmitted wheel-load stresses. It more evenly distributes stresses over a wider tire-contact area. However, we must exercise caution when reducing tire pressure. Total reduction must not exceed 25 pounds per square inch (psi) per tire. If the pressure reduction drops below 25 psi per tire, excessive tire deformation may occur, resulting in damage to the sidewall or inner tube. Reducing tire pressure also lessens the driver's discomfort from road surface roughness.

Reduce Vehicle Speed. In conjunction with reduced tire pressure, a lower speed assists in more even distribution of shock waves through the soil. Reducing shock waves helps preserve the drivers' comfort.

Reduce Vehicle Weight. Decreasing the vehicle load offers the greatest potential for extending road life while preserving the drivers' comfort. When planning throughput estimates in remote areas, transporters normally use the cross-country load weight, which is approximately 75 percent of the vehicles' rated capacity, as a base calculation. Reducing the estimated cross-country cargo load from 7,500 to 6,000 pounds reduces vehicular-caused road deterioration.

The best potential for retarding road deterioration is to use a combination of all three alternatives. This common-sense approach can be broken into several independent actions. Transporters should apply the alternatives in response to changes in weather and road conditions to extend road life and lessen potential damage to their trucks' suspension components.

Figure 4 illustrates the net effect gained from these alternatives.

- Situation I reflects no action taken.
- Situation II reflects reduced tire pressure.
- Situation III reflects reduced tire pressure and reduced payload.
- Situation IV reflects reduced tire pressure and a reduced payload of 1,500 pounds below the normal cross-country planning load.

Calculations are based on research conducted at the U. S. Army Engineer Waterways Experiment Station, using an Army series M923 5-ton cargo truck with a cargo weight of 10,000 pounds.[4] The wheel load was calculated using the vehicle's rated load capacity of 10,000 pounds and its manufactured empty weight of 22,515 pounds. As illustrated, Situation IV indicates the greatest potential for increased road life span. An interesting observation between Situations III and IV is that reducing the cross-country payload and reducing tire pressure significantly increases the life of the road.

Conclusion

The physical and political environments of a host nation influence the execution of military operations. Infrastructure limitations due to the remoteness of an area, combined with ever-changing political considerations, present unique challenges for our military forces. There is a direct correlation between road usage and road degradation and their effects on limiting convoy throughput operations. This correlation has significant influence on vehicle speeds, surface roughness, and vehicle maintenance. The alternatives discussed above are possible solutions to this problem. Reduced vehicle loads and tire pressures may potentially double road life. It is critical that military transporters understand the correlation between traffic and road degradation and between vehicle speeds and surface roughness.

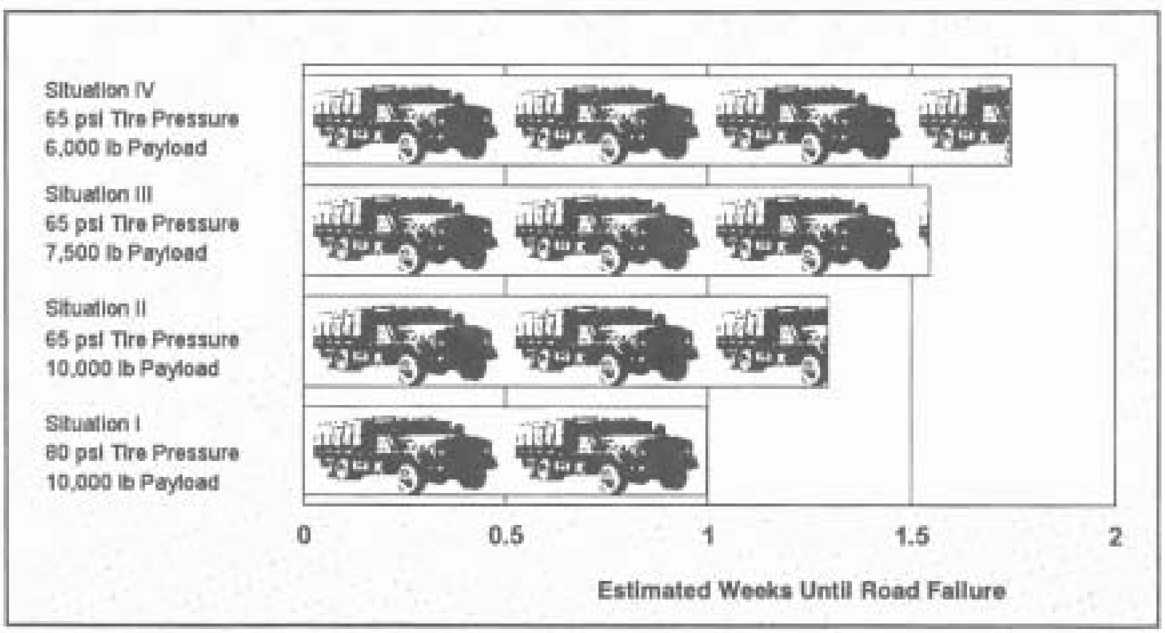

Figure 4. Estimated changes in road life based on vehicle configurations.

Engineers have limited assets for maintaining road networks. Therefore, military transporters must help reduce damage to roads in order to increase their longevity. As the focus of our force projections shifts toward humanitarian operations, more emphasis is placed on reducing overall operational costs and improving timely execution. Each member of the humanitarian team must strive to preserve the infrastructure while maintaining daily throughput operations.

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Endnotes:

[1]Mason, G.L., R.P. Smith, M.W. Gray, and R.B. Ahlvin, "Development of a Terrain and Road Data Base for HML Transporter Concepts" *Technical Report GL-85-12,* U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 1985.

[2]Cernica, John N., *Geotechnical Engineering,* Holt, Rinehart, & Winston, Inc. 1982, page 156.

[3]Wong, J.Y., *Terramechanics and Off-Road Vehicles,* Elsevier Publishing, 1989, page 198.

[4]Barber, V.C. and N.R. Murphy, "Vehicle/Road Compatibility Analysis and Modification Systems, (VRCAMS)" *Technical Report S-73-13,* U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 1973

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lengthened the ramps so the float bridge's length could be adjusted to the water level.

Clean-Up Operations

After the Finns blew charges in the water to clear the foliage, they brought in an excavator to clean up roots and debris. To allow them to reach farther across the water, we laid out the AVLB so they could move the excavator onto the bridge. This was the second time we had used the AVLB in a nontraditional role.

The Finns had a bucket loader with a revolving street broom attachment, which we used to sweep the large parking lot. It is a very efficient and useful device.

Lessons Learned

Most important, we learned that engineers must maintain a wide variety of equipment to accomplish the myriad of tasks expected of them. This can be accomplished in two ways:

- Continue to task organize units as required to accomplish the mission. This may include equipment from other nations as well as U.S. assets.
- Tailor a battalion-sized unit to give it bridging, horizontal and vertical construction, and combat engineering capabilities. (Task Force Volturno is a good example of how successful a diverse engineering unit can be. See article on page 2).

We also learned that there is a continued requirement for better countermine equipment. The Panther with its desert rollers was helpful, but it often failed to detect mines. Until technology provides us with that "ultimate" piece of countermine equipment, we must continue to use every tool available to reduce and eliminate the mine threat in every situation we encounter.

Captain Reed is attending CAS3 and will attend the University of Washington this fall. Previous assignments include Commander, B Company, 16th and 54th Engineer Battalions; and XO/platoon leader (during Desert Storm), 1st Engineer Battalion. He holds a bachelor's degree in industrial technology from Southern Illinois University .