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Vital Links: Roads and Light Railways in the Military Operations of the Canadian Corps during the First World War

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Résumé de l'article

Pendant l'offensive des cent jours de la première guerre mondiale, le Corps canadien sur le front occidental a joué un rôle important dans les opérations britanniques, qui dépassait de loin sa taille modeste de 100 000 soldats. Le Corps canadien a réussi à atteindre tous ses objectifs au cours des cent derniers jours, en partie parce qu'il disposait d'une fonction de soutien au génie et à la mobilité bien développée, opérant sur un réseau de transport multimodal. Ce réseau était constitué d'un groupe d'acteurs non humains composé de routes et de voies ferrées légères utilisant une combinaison de transports hippomobiles, de camions à moteur, de chars de ravitaillement et de tramways, soutenus par un groupe solide d'acteurs humains sous la forme d'ingénieurs et de corps de service de l'armée pour assurer l'acheminement des approvisionnements.

Vital Links: Roads and Light Railways in the Military Operations of the Canadian Corps during the First World War

Bradley Shoebottom

Abstract: *During the Hundred Days Offensive of the First World War, the Canadian Corps on the Western Front played a significant role in British operations that far outweighed its modest size of 100,00 troops. The Canadian Corps successfully took all its objectives in the last hundred days, in part because it had a well-evolved engineer and mobility support function operating over a multi-modal transportation network. This network consisted of a group of nonhuman actors made-up of road and light railway using a combination of horse transport, motor lorries, supply tanks, and tramways backed by a robust group of human actors in the form of engineers and army service corps to ensure the supplies moved forward.*

Résumé : *Pendant l'offensive des cent jours de la première guerre mondiale, le Corps canadien sur le front occidental a joué un rôle important dans les opérations britanniques, qui dépassait de loin sa taille modeste de 100 000 soldats. Le Corps canadien a réussi à atteindre tous ses objectifs au cours des cent derniers jours, en partie parce qu'il disposait d'une fonction de soutien au génie et à la mobilité bien développée, opérant sur un réseau de transport multimodal. Ce réseau était constitué d'un groupe d'acteurs non humains composé de routes et de voies ferrées légères utilisant une combinaison de transports hippomobiles, de camions à moteur, de chars de ravitaillement et de tramways, soutenus par un groupe solide d'acteurs humains sous la forme d'ingénieurs et de corps de service de l'armée pour assurer l'acheminement des approvisionnements.*

Keywords: First World War, Logistics, Engineers, Roads, Light Railways, Actor Network Theory

During a planning conference for the Battle of Passchendaele in October 1917, Canadian Corps Brigadier General Pierre Radcliffe expressed the view that "The whole question was matter of Artillery and roads…The two main roads [from Ypres] are good up to a point. Beyond that it becomes a question of whether the tracks and tramways for feeding the guns away from the main route could be laid in time."[1] In the case of Passchendaele, three years of fighting had destroyed terrain and transportation infrastructure, complicating resupply by road. In contrast, a previous operation at Hill 70 in August 1917 had primarily used light railways for the transportation of ammunition, food, animal forage, and engineering construction material. During the last Hundred Days Offensive (August 8 to 11 November 1918) of the First World War, the Canadian Corps successfully took all its objectives against the Germans because it had developed a sophisticated multi-modal transportation network consisting of roads and light railways that facilitated the movement of trams, horse transports, motor lorries, and supply tanks — which was supported by a robust engineering capability that far exceeded the capabilities of any of the other Imperial divisions and corps. This transportation network is the subject of this article, which focuses on the road and light railway network and explores how the Canadian Corps introduced engineering innovations—such as new

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road types, tramways, and the reorganization of services—that capably responded to the logistical challenges of industrialized warfare.

Technology discussions about the First World War often neglect transportation networks as a part of a greater complex of wartime technological systems.[2] The existing literature of transportation infrastructure and logistics on the Western Front during the First World War typically focuses on national production problems at the strategic level and provisioning entire theatres of war, or at the tactical level of supplying frontlines over shell-torn ground into trenches.[3] In standard accounts, the emphasis is placed on humans rather than technology, materiel objects, or how they are connected or combined into a network to provide a transportation solution. The creation of new techniques in roadbuilding suggests an evolution in technique, and the implementation of light railways into military operations at the corps and divisional level reflect a revolution in wartime transportation at the front.[4] Both require a deeper analysis of the network of relationships between these transportation systems and the people that designed and built them.

Actor Network Theory

This paper employs Actor Network Theory (ANT) to explore road and light railways as nonhuman actors in the technological environment of the First World War, uncovering how various actors understood transportation and supply and the problems they encountered.[5] The human actors at the core of this study are the Canadian engineers and pioneers who built and maintained roads, the Canadian Army Service Corps that carried supplies on and for roads under repair; the Ammunition Column units carrying ammunition for artillery; the men operating the light railways and tramways; the infantry who provided labour parties to build roads; and the infantry, artillery, and cavalry who used roads to move forward into battle. The nonhuman actors included road signs, topographic maps, hand tools, motorized and unmotorized vehicles, horses and mules, soil condition, and engineering construction materials such as gravel, cobblestones, brick, and planks. Likewise, weather, enemy shellfire, and bombs represented nonhuman actors that could slow down construction or movement. Finally, the roads, tracks, bathmat trails, light railways, and tramways represent both actors and intermediaries connecting other actors. They are an actor when being built, repaired, or as a target. They are an intermediary network in a complex system when they connect the forward battle zone with the rear as a line of communication, or when the hazard of the work on the transportation network when under shellfire becomes an issue of difference of opinion between an engineer in charge of road construction and an infantry officer in charge of an infantry road work party.

Using ANT, roads and light railways gain agency in conjunction with the humans and animals that transited it, illustrating how the road and light railways played a key role acting as an extension or local delivery network of the strategic broad-gauge railways linking the trenches and guns with the rest areas and supplies.[6] Roads and railways were not neutral infrastructures during the war; they became a tactical objective much like hills or towns or targets to be harassed with artillery. This descriptive methodology permits contextualization of multiple facets of a transportation system including the planners, designers, builder, maintainers and even those that tried to destroy it. The method also shows how roads and railways had a simultaneous duality as a part of network connecting humans where they functioned both as places of death and vital connections for lifesaving treatment.

In the process of tracing the transportation network the Canadian Corps built it will become clear that British and Canadians military leaders had contradictory thoughts about what the transportation network should look like, requiring the two nationalities to individually reflect organizational improvements, modifications to technology, and even the adoption of alternative technologies to expand the constrained networks they had conceptualized. This exception to the anticipated "norm" requires exploration since so much of twentieth century mobile warfare became synonymous to the transportation problems experienced in the First World War.

Human Actors: Engineers

Engineers are key actors in the Canadian Corps building and repairing roads, among other tasks assigned to military engineers. At the beginning of the war, Canadian divisions, much like their British counterparts, had a Commander Royal Engineers, who planned and coordinated work of the three Field Engineer Companies in consultation with the divisional commander and three brigade commanders.[7] One field engineer company of 231 men typically supported each infantry brigade of 5,000 men in constructing roads, bridges, trenches, dugouts, and water supplies. When the Canadian Corps formed in September 1915, the corps obtained a Chief Engineer (CE) with just three staff members like any British Corps, but he commanded no subordinate field engineer companies or pioneer battalions. He was merely an advisor and planner to the Corps Commander and General Staff. Also, when it became a corps, the Canadian Corps was entitled to one Army Troops engineer company for each division in the corps to execute the Corps Commander's corps level engineering tasks. In the Canadian Corps, these Corps Army Troops Companies specialized in functions such as water supply, bridging, light railways, and sawmilling. There was eventually five of them because the corps was intended to have five divisions. However, the CE and his small staff had no time to oversee and coordinate these five companies being fully occupied supporting the Corps Commander.

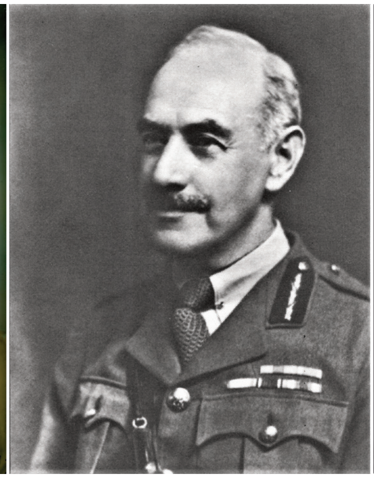
During the Battle of Vimy Ridge in April of 1917, the CE in every British Corps obtained better control of corps engineer units to achieve the Corps Commander's corps level tasks with the creation of the Commander Royal Engineers (CRE) – Corps Troops. This new position commanded the Army Troop Companies and provided greater oversight and coordinated with the CREs in the divisions to borrow the divisions engineers when out of the trenches. This corps level separation of labour freed the CE from day-to-day operational command issues and left him free to advise and plan for the Corps Commander. The CRE reported to the CE and in effect operated as his operations officer and coordinator. Beginning in March 1916, Brigadier General William Bethune Lindsay (Fig. 1) became the Canadian Corps CE and played a key role in the expansion of the engineers working on transportation networks and in the thought process behind their development. The CRE – Corps Troops was Lieutenant Colonel

H.T. Hughes (Fig. 2), a British officer who took over the new Corps Troops function at Canadian Corps in May 1917 but had been working with the Canadians since 1916.[8] Hughes also now had at his control, when not being used by the forward divisions, five pioneer battalions of 1,000 men, and four employment companies of reinforcement soldiers waiting to be sent forward to battalions. He too played an influential role in how engineers accomplished the task of road and light railway construction.

The Battle of Passchendaele in October-November 1917 proved to be one of the most difficult transportation engineering tasks the Canadian Corps faced trying to cross the shell torn fields after three years of combat. Hughes's post-Passchendaele thoughts on roadbuilding concurred with the earlier Australian army observations at Passchendaele in September and October 1917. One observation was that it was better to push forward a double plank road because of the tendency, especially by the artillery, to set up on the graded but unfinished lane thus delaying and obstructing work for the second lane.[9] Further, Hughes advocated that the artillery should not fire over roads and not be located closer than 200 yards from any road or railway and tram line to avoid counter battery fire impacting roads. Finally, he thought that roads should be considered closed until finished to prevent traffic from interfering with construction suggesting impediments to traffic such as barbed wire fencing, barricades, and traffic control soldiers to limit access.

As for manpower in 1917, both Hughes and Lindsay realized that they did not have enough with just the field engineer companies and pioneers and could not rely on infantry work parties or even pioneers. Lindsay advocated for and received Canadian Corps Commander, Lieutenant General Arthur Currie's support in submission to the British Expeditionary Force (BEF) General Headquarters (GHQ) for converting field engineer companies into full battalions, the only corps out of 22 in the BEF to do so.[10] Hughes supported these recommendations because the roadbuilding efforts left no engineering capability for assisting in telephone cabling, entrenchments, water works, bridging, or camp construction. Thus, during the winter and spring of 1918, the engineer field companies expanded into 1,000 person battalions. As well, four dedicated infantry works companies replaced the employment companies to provide manual labour exclusively on engineer projects such as roads, tramways, light railways, trenches, and load/unload both engineering construction material and ammunition. In comparison, British Corps were greatly hampered for the remainder of the war in building light railways and roads at the Corps level because they had significantly less engineers.

Hughes confirmed previous Canadian thoughts about plank road building from Vimy Ridge that plank roads were a faster construction technique than the British tendency to repair existing roads, which were frequently not wide enough. Building plank roads provided the chief advantage that engineers could safely and accurately predict construction progress rates to meet the commander's plans in comparison to trying to repair gravel or cobblestone roads. The lessons at Passchendaele showed that engineers could not build 400 yards of road a day like at Vimy; rather, that 250 yards a day of single plank road was more feasible with a daily manpower effort of 2,600.[11] Building the road was one aspect of the transportation network, but operationalizing the network meant ensuring an adequate throughput of traffic.


Figures 1-3 *(left to right): Canadian Corps Chief Engineer, Brigadier General William Bethune Lindsay. Source: Museum Strathroy-Cardoc, Ontario. Commander Royal Engineers – Canadian Corps Army Troops, Lieutenant Colonel H.T. Hughes. Source: Canadian Battlefields Memorial Commission, Canadian Battlefield Memorials (Ottawa: King's Printer, 1929). Canadian Corps Deputy Adjutant and Quarter Master General, Brigadier General George Jasper Farmar. Source: National Portrait Gallery, London, 1931, item x167486.*

Human Actors: Transportation Users

Another important group of human actors are the users of the transportation network. Roads and light railways provided users a greater ease of travel or efficiency of connecting production or cultural centers and activities, and in the case of war, destructive activity. Human actors that operated on the roads included the transportation units moving supplies as well as marching infantry and artillery. Transportation units consisted of horse transport and motor transport. Motor transport hauled ammunition from the Corps and Divisional artillery reserve parks to the horse transport of the Divisional ammunition column. There was also a motor transport column for supplies later in the war at corps level. The Deputy Adjutant and Quarter Master General (DA&QMG) for the Canadian Corps, Brigadier General George Jasper Farmar (Fig. 3), from June 1916 to the end of the war, coordinated transportation policy considering the needs of the infantry and artillery and requested engineers build additional transportation links to make the corps commander's plans possible. The Corps Senior Mechanical Transport Officer (SMTO), beginning in 1917, was responsible for coordinating the use of motor lorries to whichever divisions needed them the most. In the late spring of 1918, after consultations the previous fall, British directives concentrated all motor lorries at corps level under the control of the SMTO.[12] This caused ammunition supply problems during three battles in the last hundred days offensive, when a lack of telephone and telegraph communications and a shortage of horses and motorcycle dispatch riders caused delays; lorries often did not have the latest information about where to meet the horse drawn ammunition column to transfer ammunition.[13] A special conference among military officials in the Canadian Corps in September 1918 helped to iron out the problems. At a lower level, traffic orders provided the information and route directions when escorting convoys or when issuing trip instructions to an individual driver.[14] Motor lorries had specially trained drivers in this era of largely horse drawn transportation. On some occasions, lorries had two drivers working in twelve-hour shifts to maximize operating time unlike horses which needed eight to twelve hours of rest.[15] To prevent congestion on the roads, horse team drivers were given a pocket-sized aide-memoire on things to do such as not stopping in intersections when lost or advancing past an instruction 50 yards before pulling over to the right to wait or unload.[16]

Nonhuman actors

Nonhuman actors associated with the road and railway that gain agency utilizing ANT include the types of transport, the composition of the road and railway infrastructure, and other actors needed to navigate the human inspired system of roads and railways. Vehicles are the mechanism of movement in the transportation network. Traditional modes included horse transport varying from one-ton capacity general service wagons, water carts, horse drawn artillery, and bridge trestle wagons for the Royal Engineers.[17] The new mode harnessed steam and oil powered engines and included light railway locomotives and their wagons, the three-ton motor lorries, ambulances, staff cars, motorcycles, bicycles, tanks, and caterpillar and wheeled traction engines towing heavy artillery guns.[18] Servicing the motor transport included specialized first aid lorries or tow trucks to repair or tow broken down lorries; and mobile ordnance workshops repaired both motor and horse transport as well as fixing guns and other technology devices. Beginning at the Battle of Cambrai in late November 1917, supply tanks operated in the trenched forward battle zone that was impassable to motor and horse transport although tanks did not use roads or tracks except for the approach march to the battle zone.[19] For transport, the Canadian Corps had 960 three-ton lorries by 1917 and 4,650 one-ton horse drawn wagons and limbers pulled by approximately 24,000 horses. This allotment exceeded the standard British Corps by 25 per cent because of the extra Corps transportation units reflecting a five-division corps structure that only had four divisions.[20]

To service a corps logistically from a system perspective, the rear area or non-battle area had forward and rear areas with different types of controls and traffic expected on the road segments. For example, mules carried ammunition over the last two miles exclusively unless there were light railways to the guns. To prevent the loss of lorries from shelling, they were not permitted to come any closer than two miles from the front. Roads and railways required other constituent nonhuman actors like culverts, ditches, bridges, and fencing. Other transportation nonhuman actors included facilities such as vehicle parks for motor vehicles, hard standings for horse shelters, railways sidings and loading docks, junctions, maintenance sheds, and traffic control posts and signage. To simplify traffic control, vehicles had markings with standard signage so traffic control personnel could identify units or functions as well as road signs to communicate to drivers' directions and safe and unsafe routes.[21] Further, maps (Fig. 4) needed constant revision and reissuing to illustrate these changes. Every time a corps moved (and the Canadian Corps moved laterally at least nine times during the war) meant issuing new maps, learning new routes and roads and rail networks, making improvements, and establishing new routes or abandoning of old routes.

The weather and soil conditions also acted as an additional choke or throttle on the

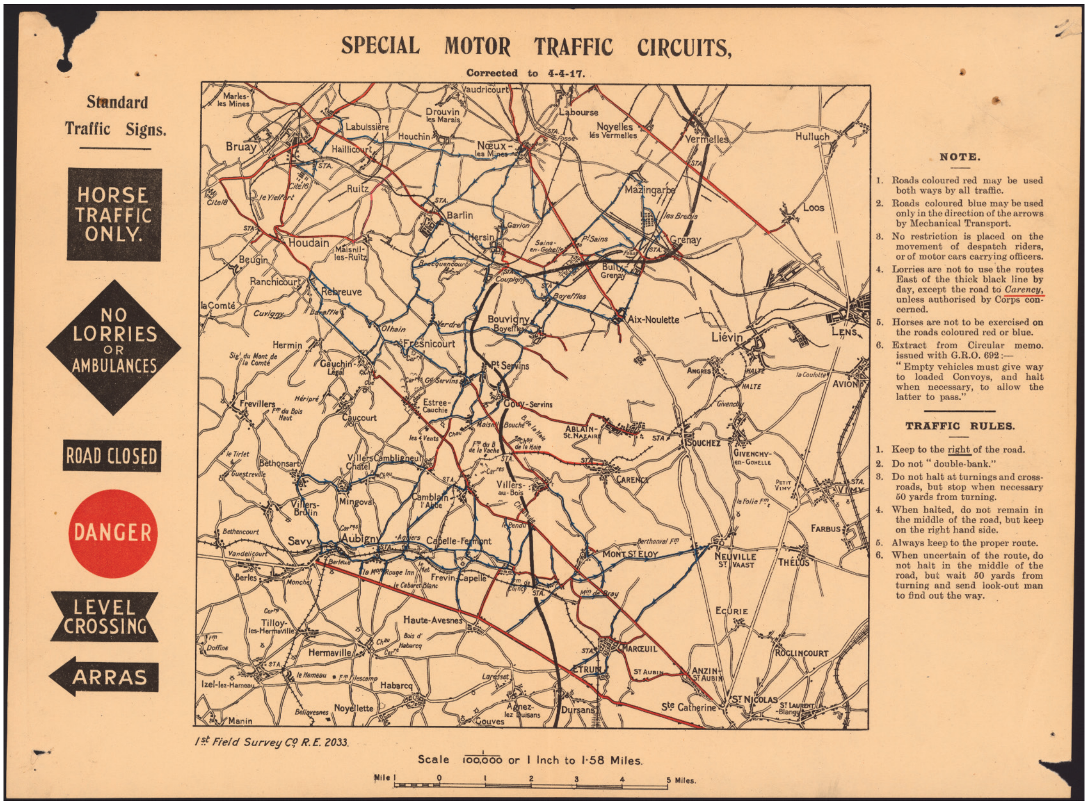


Figure 4. *Traffic Map, Vimy Ridge Sector April 4, 1917, just prior to attack. Vimy in located on the far right, center. Red routes are bi-directional roads, blue routes are one-way. Source: 1st Field Survey Company, RE 2033, Special Motor Circuits, April 4, 1917, file 2, folder 94 vol. 3954, RG9-III-C-1, Library and Archives Canada.*

capacity of the transportation network.[22] Wet weather made dry weather dirt tracks impassable requiring improvements as seasons changed. Rain overwhelmed culverts and damaged roads and bridges. Soil conditions also played a role. The Passchendaele area was known for its clay-like mud; the Somme was much dryer chalk-like soil which permitted better overland travel but even it could turn muddy after three months of shelling. The time of year also impacted operations on roads. The fall freeze and spring thaw caused frost heave moving pavement stones. Therefore, heavily loaded motor lorries remained parked for two weeks to prevent damage to the road surface which then necessitated supply buildups prior to thaw precautions or a shift to using light railways.[23] Even horse drawn transport operated at half loads during the thaw. Operations typically ceased from December to February for both sides in the war. In the summer, dirt tracks and local gravel roads dried up and fast-moving lorries created dust clouds attracting German ground attack aircraft. Speed regulations were necessary, typically 12 miles per hour for lorries, even on first class roads because many became covered in mud. Speed limits in villages were six miles per hour for lorries and ten for ambulances and cars.[24] Senior officers viewed court martials for speeding offenses as a necessary technique to remind drivers to preserve the surface of the road when road metal was short.[25] The next two sections discuss the construction of roads and light railways to understand the magnitude of the effort needed to create these transportation networks.

Roads as nonhuman actors

A road and its constituent elements are nonhuman actors for the human actors in a transportation network within ANT analysis. Road maintenance or construction needed vast quantities of sand and cobblestone, a rare commodity in wartime France. Instead, engineers temporarily patched roads with rough quarry rubble or gravel.[26] However, gravel was always in short supply and substitutes included softer chalk and sometimes mine tailings. Bricks from destroyed buildings provided fill for shell holes. Canadian engineers advanced the idea of plank roads, however, plank roads required vast amounts of pre-cut lumber and spikes but were a savings on the volume of gravel. Plank roads (Fig. 5) needed only 33 per cent of the lorry loads of engineering construction materials for the same distance constructed and could be built twice as fast. At Vimy in April 1917, Canadian engineers limited road construction to repairing the damaged pre-existing roadwork instead of expanding it because there was a comprehensive light railway system that rendered the need for extra motor transport unnecessary. However, plank roads restricted traffic to mostly horse and motor lorries; tanks and caterpillar tractors were too heavy for the light surface and pivot turns would damage the surface too easily.

Another labour-intensive nonhuman actor in the transportation network was the bridge. Prewar field engineering manuals emphasized infantry foot bridges, pontoon bridges, and expedient crib and wooden truss bridges for heavier loads.[27] Prewar, there was no prefabricated bridge designs or components. Battle experience during rapid advances in March 1917, at Vimy Ridge and Passchendaele, lent urgency to the need for prefabricated bridges as well as more information about bridging. A British

Figure 5. *Laying a road over the crest of Vimy Ridge. April, 1917. Source: PA-001226, box number: 83,7435, 15, O-1261, Library and Archives Canada.*

bulletin for engineer officers in January 1918 entitled "Organization of Bridging Work" outlined the needs for planning and estimating bridgework.[28] The majority of the critical engineering work for the Canadian Corps in the last hundred days involved bridging ten major canals or rivers, often with up to half a dozen bridging sites using the newly available prefabricated Inglis, Weldon, and Hopkins trestle bridges.[29] In the winter of 1917-18, in anticipation of a more mobile warfare, the BEF re-authorized all 22 corps to form a company of pontoon and trestle bridges, returning to the 1914 doctrine for crossing waterways for both infantry and lighter vehicles.[30] However, bridges came with some limitations. Prefabricated Inglis bridges could not easily accommodate taller vehicle types like the double decker troop transport busses.[31] Likewise, tanks required studier bridges for their 27-ton weight. With prefabricated bridge technology came the requirement for special seven-ton trailers, longer pontoon trestle wagons, and five-ton steam powered Berna lorries to carry these heavier and longer trestles.[32]

Despite the rapid degree of innovation from 1870 to 1914, very little mechanization existed for road construction in 1914 and what there was largely followed a pre-industrial method requiring significant human actors for construction. Little had changed since the era of *corvée* forced labour for building roads in the 1700 and 1800s. Industrial-era construction technology for roads was rare and limited to large scale bridge or tunnel construction projects. Most roadwork used manual labour to dig, pile, flatten, lay, and fasten roads. Worker's tools included pickaxes, spades and shovels, wheelbarrows, hammers, hand drills, mud scoops, and wire cutters. Contract French and Belgian manual labour and occasionally soldiers broke rocks with sledgehammers.[33] The only British steam shovels used in France were large railway bound quarry steam shovels. There was also a limited supply of steam rollers for compacting gravel roads in the army and corps rear area with the Canadian Corps having three; these were never seen in a divisions area or forward area. Moreover, there were no powered graders or excavators, bucket loaders, backhoes, forklifts, or even dump trucks. The available horse-drawn drag scrapers remained confined to railway excavation. The only truck available for carrying earth or gravel was a fixed-bed (non tipping) lorry with a 1.5- or 3-ton capacity. Loading both lorry and wagons was done by hand with shovels and unloaded in the same way. Therefore, engineers preferred to build pushcart tramways and light railways because they could carry larger quantities of bulky and heavy engineering construction materials and had tip mechanisms.

Due to the lack of mechanized construction equipment, roadwork parties needed large bodies of workers as human actors. When Lindsay became chief engineer of the Canadian Corps in March 1916, he cabled Ottawa to send bitumen spreaders and ditch diggers, but conversation with the BEF chief engineer about a lack of bitumen and limited use for the ditch diggers caused him to cancel the request for technology that had limited wartime application.[34] At the Battle of Amiens on 8 August 1918, there was a slight improvement in productivity when Chief Engineer Lindsay asked for and received from the 4th Army some tip-carts to speed the unloading of road stone since there was less narrow gauge railways in this sector.[35]

One might wonder how it was that the rapidly expanded Canadian army transferred knowledge about new building techniques and methods. The Canadian Militia did not publish military engineering manuals before or during the war. Instead, they relied on the official British *Manual of Military Engineering*, issued in 1905, 1911, and 1914.[36] However, these manuals did not suggest the concept of plank roads. Canadian engineering officers educated at Canadian universities would have been familiar with W.M. Gillespie's *A Manual of the Principles and Practice of Road-making* (1868), and soldiers would have been familiar with the road building techniques mentioned in General Garnet J. Wolseley's *The Soldier's Pocket-Book for Field Service* (1871-72).[37] Edwin C. Guillet considered Canada a world leader in plank roads in a country with so much forest.[38] Plank roads were common in Canada and the United States for streets and roadways in rural areas.[39] Due to this shortage of knowledge about road construction techniques, GHQ issued various pamphlets that included the Canadian plank road method, particularly in 1917 and 1918, to disseminate knowledge to engineers who may not have had a copy of the 1905 edition nor wartime training in the Canadian plank method. The Canadian lessons learned in roadbuilding in 1917 and particularly at Passchendaele became codified in the winter of 1918 as "Notes on Forward Road Construction," for BEF-wide distribution.[40]

To further complicate transportation operations, mules in the forward area refused to travel on single lane roads with motor traffic requiring additional parallel mule tracks. At Passchendaele, the Canadians redesigned the standard British pattern mule mats into half width plank roads made into prefabricated eight-foot sections that could be rolled up for transport. These mule mats needed improvement because mules also refused to travel on "mule mats" woven from branches like fascines that lacked a firm footing. As Lieutenant Colonel Thomas Craig Irving, Commander Royal Engineers, 4th Canadian Division noted: "mats of split pitprops, rounded side up, are said to be unsuitable as mules don't like walking on them and are apt to draw their shoes off; mats of split pit props, flat side up, are said to be better, but are heavy to carry up."[41]

At the corps level in the BEF, there was no exclusive roadbuilding function. If roadwork was a priority, the chief engineer had to negotiate with the CRE of each division to release the three field engineer companies and the pioneer battalion. At the divisional level, field engineering companies erected bridges and laid plank roads, but they often did not have enough personnel, so they utilized pioneers and infantry work parties who brought up the engineering construction material, graded roads, and excavated ditches. There were labour companies such as the 4th Canadian Labour Battalion, but these soldiers were less physically able soldiers, often previously wounded or shell shocked, and not as fit to complete hard and prolonged work. Division employment companies became available at times, but since their primary role was as a holding unit for reinforcements, soldiers rarely had time to learn much about roadbuilding.

Light Railways

Using the ANT analysis and methodology, railways and their constituent parts represent the other key nonhuman actor in the transportation network. Construction of light railways and tramways required a firm and flat roadbed, otherwise the railways bent with the standard six-ton loads on light railways and three-ton limits on tramways. Typically, light railways and tramways followed the contour of the land, snaking around hills and avoiding waterways while trying to maintain a hill or other sight line block barrier to prevent enemy observation.[42] In 1917, the 2nd Canadian Railway Battalion (CRT), as part of the 13 battalions of Canadian railway troops sent to France in 1916-17 to build broad gauge railways, experimented with three different light rail building techniques before settling on a special rod and clamp that attached to the prefabricated rail sections and allowed eight men to carry a section overtop of the men connecting the previous section to the line without disrupting work. This unit then established a light railway construction school on 1 July 1917 in Watou, France, to spread the knowledge under 2nd and 5th Army Assistant Director of Light Railways.[43] They found that if the ground was particularly soft, like it was at Passchendaele, planks or sleepers would be lain between metal sleepers on the prefabricated track to decrease the ground pressure. The 2nd CRT found that a good crew could lay up to 2,500 feet of track in a single six-hour shift during training. This was rare in the field because of track shortages, arrival delays, a shortage of labour to assist with grading, or the enemy interfered. The 2nd CRT also found that if any more than 25 men per hundred feet of grading would result in pick injuries. Typically, each mile of light railway required 1,750 to 2,400 person days a task that a Railway Construction Battalion could do in two to three days.[44]

By late 1917, a standardized Canadian design evolved for the layout of light railway supply dumps (Fig. 6) and replenishment points. Light railways and tramways rarely remained in place for long, moving as the front moved or requirements changed. To expand light railway networks and overcome a shortage in prefabricated track sections, many light railways used scavenged material, especially during the last hundred days when the front was moving quickly forward. Lifting old track and using captured German track became common. The Canadian Corps tramways companies constructed or converted over 50 miles of mainline track and 50 miles of spurs while moving a maximum of 3,284 tons a day in October 1918, a far cry from the 320 tons a day prior to the battle of Vimy Ridge in March 1917.[45] While the light railways locomotives and train cars came from standard British designs, Canadians modified them to act as mobile repair cars, observation cars, and to make artillery more mobile during the much-anticipated German spring offensive of 1918. However, these cars were few in comparison to the thousands of British designed flatcars and wagons.

Where the Canadian Corps had a more significant impact was in the creation of a corps level light railway construction and operating companies. These two ad hoc companies from 1916 proved their value at the Somme, Vimy Ridge, and Hill 70. From the engineering experience at Passchendaele and Hill 70, Hughes noted that light railways were useless unless they could push forward quickly, which was unlikely in soft terrain or when under enemy observation since locomotives were high value targets to the Germans.[46] Therefore, pushcart tramways could be built faster and with less stringent design requirements that could keep pace with the advance. But tramways needed building under a singular organized unit, and not assigned to a changing rotation of Field Companies like at Passchendaele, or there would be no sense of ownership of the construction. Therefore, Hughes, Lindsay, and Currie advocated for and received permission to form the only corps level Tramway Operating Company and Construction Company in the BEF in November 1917 while the rest of the BEF

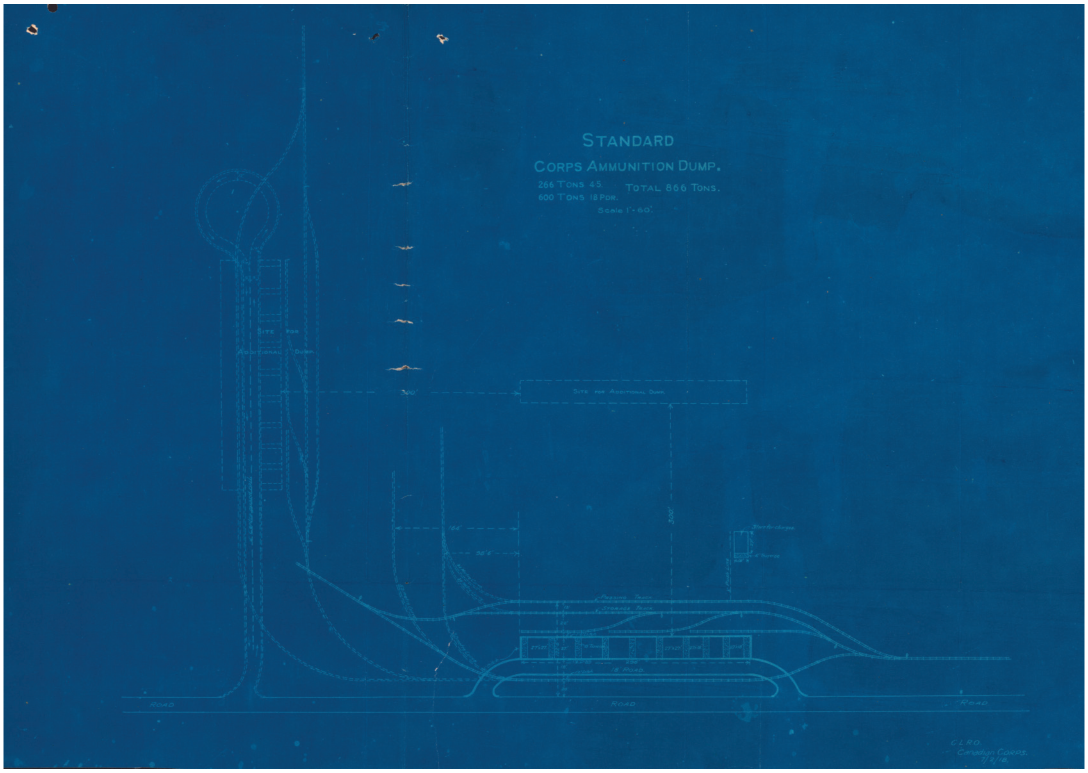


Figure 6. *Standard Corps Ammunition Dump March 1918. Source: Lt Col WB Anderson, AQMG Canadian Corps to 1st to 4th Division "Q", Chief Engineer, AD Light Railways, Canadian Corps Ammunition Park Q/13/17/1 "Standard Corps Ammunition Dump", file A-86-3 (vol 2), vol. 882, RG9-III-B-1, Library and Archives Canada.*

had to wait until late winter 1918.[47] The Canadian Corps became the only corps to have tramway companies from 1916 until February 1918 when the British finally authorized Foreways Companies to build within the corps area of responsibility. However, the British only formed four Foreways companies for the 22 Corps due to manpower shortages in 1918. By this point, the Canadian Corps increased the size of its tramway companies by another 100 men to enable the companies to leapfrog forward during more rapid advances.[48]

Indeed, many nonhumans contributed to the road and light railway network often comprising their own subsystems. Changing one nonhuman actor such as removing lorries from service required other nonhuman actors like light railways and horse drawn transport to increase their operational tempo and capacity. An examination of the human actors will also show that complexity of the transportation system required more specialization of personnel and units.

Resistance within the network

In ANT, success or failure of a technology is often conditioned by the ability of some actors to "enrol" or "mobilize" other actors in extending, stabilizing and strengthening the networks they aim to build.[49] On the other hand, for various reasons, some actors, whether human or nonhuman, might hinder the achievement of these objectives by "resisting" the enrolment process.[50] Resistance within a network may not actually originate from people but from competing technologies, legacy systems, or unforeseen challenges. A significant question regarding plank roads was whether various users reacted favourably to this technology change. In the case of building plank roads, once the Canadians had proved their efficacy at the Somme in 1916, staff planning adopted this faster roadbuilding technique in 1917 at Vimy and Passchendaele, although some British Corps still built log and fascine tracks based on the logs and branches they had readily available as seen at Passchendaele when the Canadians took over.[51] There could be still many reasons why a road might not get built in the time span desired nor to the route or width desired. Often work slowdown could be a combination of these three factors. Resisters to the roads and light railways included the enemy, the infantry work parties, and thieves.

Enemy

The enemy was the chief and most obvious resister to roads. Roads could speed up the movement of men and materiel but could also canalize them along predicable routes that enemy artillery could then interdict. Artillery on both sides frequently shelled crossroads, a common location for headquarters or supply dumps. The three leading methods of German opposition in the Canadian rear were shelling, gas, and aerial bombing. Machine gun fire from the German defensive zone could not reach the road working parties but strafing by German fighters could and did. German medium howitzers had little difficulty shelling their targets at Ypres because they fired from the three sides of the British salient into the German lines. Crossroads became a focal node for the engineers and artillery and drew a German artillery fire response in return. The Germans, while retreating, and especially in the second half of 1918, blocked roads for use by tanks by cratering, usually at intersections, felled trees across roads, barricaded roads with concrete and metal, or other improvised objects, and demolished bridges. Lorry and horse team drivers often had to unload their cargos short of their destinations because of shelling. They tried to pile it to the side of the road so they could then do a U-turn and escape.

Shelling diverted the work parties from their building task to treating and evacuating their dead and wounded. Shelling could also destroy previously built work. If not being shelled by high explosive shells, the Germans frequently used gas shells to slow and disrupt roadwork and inflict injury. German aerial activity was particularly bad at Passchendaele from smaller bombers in the day and from giant Gotha bombers at night that tended to attack dumps, camps, and towns. The 123rd Canadian Pioneer Battalion loathed enemy bombers, commenting on 31 October 1917: "The Hun seems to do exactly what he liked on this front in the air which is surprising… The strain under which the battalion is working is unquestionably telling on them which is evidenced by the sick reports most of the cases being foot trouble."[52] The 2nd Field Company, Canadian Engineers reported on 9 November that, "Enemy planes out today and do a good deal of bombing. One enemy plane repeatedly attacks party working on plank road with machine gun fire, firing very low. Work on plank road greatly interfered with owing to enemy shellfire. Work has been telling on officers in men in forward area."[53] While the enemy could slow down construction, so could the workers, something that the

American industrial efficiency expert Frederick Winslow Taylor had called "soldiering" in 1911 and Latour calls worker resistance.[54]

Work Parties

Resistance also came from those building the roads or railways. It is unsurprising that engineers faced problems getting the work parties to the job site on time and keeping them there under the horrific conditions of mud, rain, and casualties. They had difficulty motivating troops to work on the road in the open, and especially in the daylight when the enemy could spot soldiers working several miles behind the lines or from aerial observation. Unlike the infantry in the 1st line or support trenches, there was no protection for work parties from shellfire or bombs, other than the ditch they were digging or a wet and muddy shell hole. Engineers, pioneers, and infantry work parties at Passchendaele suffered some of the highest losses of the war. G.W.L. Nicholson in the Canadian Corps official history notes there were 1,500 casualties while working on the roads at Passchendaele but appears to have included anyone injured while working on or transiting the roads including the infantry and artillery. My own calculations from war diaries and work reports of all engineers, artillery, and infantry units indicate 669 soldiers killed, wounded, or missing while on the roads and another 166 killed and wounded while in camp east of Ypres.[55] An analysis of Canadian Army Service Corps (CASC) casualties indicates another 185 casualties while conveying supplies and ammunition using lorries and horse transportation. Further, 13 lorries were destroyed and 27 damaged out of 105.[56] Horse casualties amounted to 643 dead and 555 wounded at Passchendaele (of the 24,000 in the Canadian Corps), by far the highest number during the war.[57] There were only two cases of obvious shell shock reported among the engineers, although several others were noted as evacuated with concussion and the 4th Army Troops Company sent five soldiers to rest camps after building two bridges under fire.[58]

The roadbuilding parties faced significant issues with the work parties throughout the battle, reducing progress, including leaving work early or not working hard enough. Canadian field engineer daily work progress reports from the war are full of remarks that the infantry work parties often left early, usually after heavy shelling or casualties.[59] While the 8th Field Company, Canadian Engineers worked on the mule track north of Panet Road on 25 October 1917, Major W. Manford appears to have been concerned enough about a work party from the 49th Canadian Infantry Battalion that he wrote a separate complaint: "Officers in charges were told job had to be finished and it would be necessary to make two trips. On the first trip the four companies carried 200 bathmats forward. 'A' Company then went home. The other three companies made a second trip but brought only a small quantity (less than 100). Apparently, some men ditched their loads and others did not come forward the second time." [60] Despite the resistance to work, an analysis of the engineering work reports and war diaries of units working on the roads indicate that "soldiering" impacted less than 10 per cent of the work effort. The roads opened on schedule during the Canadian portion of the Battle of Passchendaele. In fact, the Canadian Corps overachieved on its deliveries of cargo: the light railways delivered 1,338 tons and lorries 11,170 tons of ammunition, exceeding the light railways pre-battle estimates by 33.8 per cent, the lorries by 28 per cent, and overall, by 28 per cent.[61]

Arguably, it is easy to understand why some units were reluctant to work on roads based on their casualties. While the infantry work parties disliked road work, Private Arthur Turner of the 50th Canadian Infantry Battalion certainly appreciated the plank roads coming out of the line, even if covered with a foot of mud, compared to slogging across country at Passchendaele: "It was good to feel solid roadway underfoot again."[62] Passchendaele was by far the deadliest battle for the engineers and required the most herculean effort and coordination of the war. Roads also displayed a dialectical emotional symbol to soldiers: a negative dreading emotion while approaching the trenches or under shellfire on the road, and a positive uplifting one when moving away from the front. From the evidence gathered in this essay, the infantry placed less importance to road and railway construction projects than did the engineers, and they were less tolerant of death risks by gas or shellfire while travelling or working on roads and light railways.

Theft

Resistance also came in the form of the diversions of supplies meant for road or railway building. Shortage of engineering construction material could slow roadwork progress, but theft of planks and infantry trench or bathmats for infantry tracks was also a problem at Passchendaele. The artillery "borrowed" planks to serve as stable bases for the guns or for piling ammunition on. But a far greater problem was the theft of bathmats. The 3rd Division had a particular problem with stolen bathmats from 26 October 1917 to 7 November 1917. The CRE of 3rd Division reported the thefts of trench mats, noting "682 trench mats stolen from Tracks 5 and 6 to date. 9th Field Company [was] ordered to leave the gaps where the mats have been removed, as it is not intended to relay tracks two or three times while those for whom the tracks are intended continue to remove them."[63] The 9th Field Company believed that "long sections of the track already laid are frequently removed presumably by infantry men desiring to build bivvies [shelters] or on which to sleep. Last night [2 November 1917] 260 yards of the track in front of Abraham Heights was torn up and the mats removed. The great distance that the mats have to be carried by hand in some cases nearly four miles add to the difficulty of the work."[64] The infantry's desire to be more comfortable in their trenches and shell holes would now cost them in terms of their decreased mobility doing communications tasks on the infantry tracks and prolonging their journey coming in and out of the trenches much like the Australians had had in their previous attacks.[65] From the engineer's perspective, they could not waste engineering construction material and time of their engineers and carrying parties to continuously replace the trench mats.

Conclusion

This discussion about roads and light railways using ANT unsurprisingly illustrates that in a time of industrialized warfare and greater emphasis on broad-gauge railways for conveying large volumes of supplies, roads and light railway were still critical links in the transportation network linking the broad-gauge network to the forward local destinations within the corps and divisions. ANT helps illustrate the importance of the nonhuman actors in the transportation system. Light railways, motor, and horse transport operated in conjunction with each other to optimize the local transportation network based on conditions such as existing infrastructure, terrain, and the enemy position. This discussion noted the forms of resistance to roadbuilding efforts, including the lost hours of labour due to shelling, and morale issues with the infantry work parties. However, the larger problem lay with coordinating the engineering construction materials and arranging for their delivery to forward engineer dumps and work sites when the road network came under attack. The Canadian Corps through Generals Currie, Lindsay, Farmar, and Colonel Hughes were far more effective in convincing the British that their ideas for tramways were sound. This problem largely existed in static fronts, and when units were suddenly moved to new locations without time to establish new communications networks with Army level staff, they became used to the new road networks and established suitable traffic control measures. Despite the perceived lack of transportation, General Farmar, the Canadian Corps DA&QMG, considered Passchendaele a success from a transportation perspective:

> The work carried out by the various mechanical transport units of the Canadian Corps, during these successful operations in which the Corps have taken part, has been most excellent, and despite heavy road conditions, inclement weather, shelling and bombing, the work was carried on with vigor and interest. Seldom during the war had such a large amount of ammunition of all calibers had to be handled under such difficulties. The success of the operation was largely due to the determination shown by the lorry and caterpillar drivers in carrying out their duties. This was particularly noticeable in the transportation of engineer stores, road metal and planks etc. for forward road construction, which must be carried out before either guns or ammunition can go forward.[66]

All these changes allowed the Canadian Corps to achieve and exceed their daily ammunition and supply tonnage forecasts, thus contributing to the successful outcome of the Battle of Passchendaele.[67]

Mobile warfare brought about its own headaches by creating traffic jams when all units attempted to use road networks at the same time to move forward.[68] The Canadian Corps showed creativity in overcoming some of these hurdles by arranging for changes in railheads and by suggestions made from relatively low-ranking officers like engineer lieutenants and Army Service Corps majors for changes to routes, construction, and traffic control and patterns. Generals Lindsay and Farmar and Hughes were just three men out of tens of thousands of engineers and service corps personnel building, maintaining, and operating on the roads. Canadians also showed their technical creativity with improved road designs. Finally, the increased flexibility of the engineers through the creation of engineer battalions and tramways companies greatly facilitated the Canadian Corps mobility in the last hundred days.

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