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Commercial Transport During a Pandemic: Network Analysis to Reconcile COVID-19 Diffusion and Vital Supply Chain Resilience

To the Editor:

Population mobility and transportation are critically linked with the acquisition and spread of infectious diseases.[1] As the nearly two million US long-haul truck drivers traverse vast distances and interact with numerous individuals,[2] they unavoidably render themselves and the populations they intermingle with vulnerable to contracting and spreading re/emerging infections, including coronavirus 2019 (COVID-19). The current COVID-19 pandemic has underscored how little is known about the potential role and consequences of commercial drivers' social and spatial networks in the heterogeneous acquisition and transmission of such afflictions, as well as the corresponding impacts of these afflictions on the health and safety of transportation workers and on the capacity of critical supply chains.

When considering the potential role of long-haul truck drivers in the spread and control of COVID-19, policymakers are faced with a dilemma. On the one hand, the aforementioned risks of COVID-19 acquisition and transmission suggest that public health strategies (eg, shelter-in-place orders) are urgently needed to reduce the potential threat of disease spread via long-haul truck drivers. On the other hand, highly publicized shortages of key medical equipment[3] have magnified the critical service that long-haul truck drivers provide during the pandemic.[4] Because of this, the vital importance of keeping these drivers "on the road" to continue supplying essential goods renders current strategies impractical for this population. Thus, commercial driver network-centered research is critical for: (1) understanding COVID-19 and other re/emerging infectious disease acquisition and transmission risks; and (2) identifying innovative and practical strategies for the prevention and control of such outbreaks that also maintain the resilience of critical supply chains.

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Address correspondence to: Michael Kenneth Lemke, PhD, One Main St., Houston, TX 77002 (lemkeM@uhd.edu).

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TRUCKER NETWORKS, COVID-19 SPREAD, AND CRITICAL SUPPLY CHAINS

Long-haul truck drivers are the backbone of the US trucking industry, which moves the majority of all domestic freight.[5] Accordingly, medical supply chains are reliant on trucking and long-haul truck drivers. In the case of COVID-19, the capacity of medical supply chains to distribute adequate medical resources has been explicitly associated with improved patient outcomes,[3] and will continue to be of vital importance as treatments and vaccines are approved, manufactured, and distributed.[6] As long-haul truck drivers strive to meet the unprecedented demands due to the current pandemic, their movement patterns and social interactions are unique and of foremost epidemiological significance. In 2017, nearly 200 billion miles were recorded by commercial trucks, and these routes often vary and may include travel to Mexico or Canada.[1,5] As long-haul truck drivers crisscross the nation, they spend non-driving time in their truck cabs, as well as at truck stops, terminals, warehouses, and other worksites that represent "home."[7] It is typically in these worksites that truck drivers engage in social interactions and form heterogeneous social contacts.[8] For a typical long-haul truck driver, social contacts may include: any of the 7.8 million people employed throughout the economy in jobs related to trucking, including any of the 3.5 million truck drivers[5,8]; dispatchers[7]; non-truck driver worksite employees and customers[7]; drivers of private vehicles stopping at truck stops; and family and friends.[8]

The social networks of long-haul truck drivers along varying spatial contexts have been shown to pose infection acquisition and transmission risks to themselves and others[9] that are likely to be present in the case of COVID-19 that are exacerbated by a dearth of PPE, screening or testing capabilities, or ways for infected drivers to self-quarantine or seek treatment.[4] For example, long-haul truck driver populations have been shown to spread sexually transmitted diseases and bloodborne infections across disparate geographic and demographic lines, including disease diffusion from affected to nonaffected areas and populations.[9] However, the characteristics and properties of long-haul truck drivers' dynamic networks also represent pathways for understanding the mechanisms of COVID-19 acquisition and spread and for identifying prevention and control strategies.

IMPLICATIONS OF TRUCKER NETWORK ANALYSIS FOR OUTBREAK PREPAREDNESS

The novel insights from network science can greatly increase the accuracy of the epidemic analysis and can provide new ideas on efficient mitigation strategies that can be readily translated to public health policies. Network science increasingly focuses on understanding the behavior of real, large-scale, and complex interactions.[10] A network representation of long-haul truck drivers' interactions along their routes can highlight the intricate patterns that drive COVID-19 spread that could otherwise remain hidden if simply analyzed using traditional statistical analysis.[11] For example, a long-haul truck driver with relatively few interactions can trigger a much broader infection spread than a more well-connected truck driver, depending on the position of each in their network, relationship types, and extended network neighborhoods.[12] This is a counterintuitive result that cannot be discovered or explained without studying the complete network structure.

Network analysis of long-haul truck drivers affords researchers opportunities to explore a wealth of new properties and key ideas. For example, network analysis can be used to: (a) map the spatial and temporal dynamics of various infections[13]; (b) determine correlations of infection diffusion in time and space[14]; (c) identify super-spreaders[15]—truck drivers who disproportionately infect more secondary contacts; (d) discover possible roles that different truck drivers might play in epidemics, such as connectors between different geographical areas, bottlenecks, inhibitors, local hubs[16]; (e) identify network modules,[17] that is, clusters of truck drivers who are typically close to each other; (f) determine the interplay between network structure and disease dynamics[18]; (g) evaluate the efficacy of various immunization scenarios[19]; and (h) explore numerous scenarios on stopping or delaying infection spread and associated socioeconomic impacts, based on changes in network structure (eg, changing routes; implementing physical distancing).[20]

The analysis of long-haul truck driver networks also poses many challenges, as their networks are inherently dynamic and truck routes lead to networks that continuously evolve in time and space, so advanced methodological and analytical tools need to be employed. For example, in addition to typical network considerations, there is also an underlying network of worksites that can function as virus reservoirs; thus, even if two truck drivers are never in spatial proximity, it is still possible that one can transmit infectious agents to the other. This consideration adds an additional layer of complexity to the network approach that can be addressed either by multilayered networks or by specially constructed bipartite networks.[21]

ACTION STEPS IN TRUCKER NETWORK-CENTERED COVID-19 RESEARCH AND PREVENTION

In order to advance trucker network-centered COVID-19 research and prevention, the following four action steps are urgently warranted. First, detailed data should be collected on existing normal and pandemic-impacted driver routes over an extended period of time to allow the construction of large-scale dynamic networks of interactions among long-haul truck drivers and their diverse social contacts. Second, COVID-19 incidence, prevalence, morbidity, and mortality rates among long-haul truck drivers and their key social contacts should be established. These data, in conjunction with network data from the previous step, would allow for the analysis of the social, spatial, and temporal dynamics of COVID-19 acquisition and transmission along long-haul truck drivers' routes. Third, grounded in knowledge obtained from the previous two action steps, efficacious and practical preventive measures that curb COVID-19 acquisition and transmission among long-haul truck drivers and their social contacts while also maintaining critical supply chains should be identified. Finally, to better prepare for potential future waves of COVID-19 and other re/emerging infectious disease threats, network science-grounded mathematical and simulation models should be developed, tested, and validated. These models could then serve as tools to anticipate the trajectories of future epidemics and guide subsequent preventive measures.

CONCLUSION

The characteristics and properties of US long-haul truck drivers' complex spatial and social networks pose COVID-19 acquisition and transmission risks. Trucker network-centered COVID-19 research and prevention, grounded in network science, can exploit a wealth of new properties and key ideas that can be harnessed to mitigate disease acquisition and spread and protect vital supply chains. Thus, four action steps are warranted: (1) collecting detailed data on both normal and pandemic-impacted driver routes over an extended period of time; (2) establishing COVID-19 incidence, prevalence, morbidity, and mortality rates among drivers and their key social contacts; (3) identifying efficacious and practical preventive measures that curb COVID-19 acquisition and transmission; and (4) developing, testing, and validating network-science-grounded mathematical and simulation models for COVID-19 and other re/emerging infections.

Michael Kenneth Lemke, PhD
Department of Social Sciences,
University of Houston-Downtown,
Houston, Texas

Yorghos Apostolopoulos, PhD
Complexity & Computational Population
Health Group, Texas A&M University,
College Station, Texas

Lazaros K. Gallos, PhD
DIMACS, Center for Discrete Mathematics
and Theoretical Computer Science,
Rutgers University,
Piscataway, New Jersey

Sevil Sönmez, PhD
College of Business Administration,
University of Central Florida,
Orlando, Florida

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