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Ross O. Phillips & Siri Hegna Berge

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Sociotechnical Factors Supporting Mobile Phone Use by Bus Drivers

Ross O. Phillips and Siri Hegna Berge

Norwegian Centre for Transport Research (TØI), Oslo, Norway

OCCUPATIONAL APPLICATIONS

Results of a survey of drivers working for two bus companies in Norway suggest that 20% of drivers sometimes use a mobile phone while driving, even though it is not permitted. Sociotechnical analysis of the system surrounding drivers at one of the companies elicited ways in which social and technical factors combined to support mobile phone use by bus drivers. These factors were arranged under four themes: increased societal dependence on technology; developments in bus driver culture; the need for bus drivers to resolve conflicting goals; and a lack of belief in adverse consequences of using mobile phone while driving. Our findings (i) support claims that driver-centered analyses of mobile phone use or other traffic safety challenges are an insufficient basis for the development of measures and should be supplemented by sociotechnical analyses; and (ii) can inspire the design of more comprehensive measures to help reduce mobile phone use and road safety risks.

TECHNICAL ABSTRACT

Background: Sociotechnical measures could supplement traditional risk management measures and further reduce risks of collisions involving heavy vehicles. Such measures can be identified using methods rooted in sociotechnical systems theory, which considers that people work in systems comprising multiple social and technical elements that interact to create emergent properties and conditions that influence valued system outcomes. **Purpose:** To investigate the potential of sociotechnical measures in helping to reduce road risks, we identified how social and technical factors combine to influence mobile phone use by bus drivers working at a company in Norway. **Method:** A survey of ∼600 drivers was completed, followed by focus group interviews with managers and drivers and one-on-one or group interviews with drivers. The interviews were structured using a sociotechnical analysis framework. **Results:** Twenty percent of drivers reported using their phone while operating a bus, even though such use was against company guidelines. Almost all drivers took their phone with them when they drove, and 40% of those who said they never used their phone while driving could still hear incoming calls and messages. Analysis from nine interviews with 26 drivers suggested that phone use by drivers operating buses is supported by interacting sociotechnical factors due to an increased societal dependence on technology, developments in bus driver culture, a need for bus drivers to resolve conflicting goals at work, and a lack of consequences for drivers using mobile phone use while driving. **Conclusions:** Limited consideration of the sociotechnical ecosystems surrounding bus drivers can contribute to their mobile phone use and thereby to potential problems of attention and awareness while driving. Sociotechnical approaches should be developed using participative design to reduce phone use while driving, especially to promote openness and information sharing and support bus drivers in the field as they strive to resolve conflicting goals.

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Mobile phone; bus driving; sociotechnical road safety

1. Introduction

Over 20,000 people die and over 100,000 more are seriously injured in traffic collisions each year on roads in the European Union (EU), with societal costs of 280 billion euros, about 2% of EU GDP (European Commission, 2020). To address this problem, the EU aims to eliminate traffic deaths and serious injuries completely by 2050 (EU, 2021). Reaching this target requires a comprehensive effort to reduce the disproportionately large number of serious injuries resulting from collisions involving heavy vehicles (gross vehicle mass > 4.5 tonnes). In several EU countries, including Norway, heavy vehicles are involved in collisions that are responsible for one-third of road fatalities (Langeland & Phillips, 2016; ERSO, 2021).

CONTACT Ross O. Phillips rph@toi.no Norwegian Centre for Transport Research (TØI), Gaustadalleen 21, Oslo, 0349, Norway.
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Measures that can help reduce the risk of serious injury due to collisions with heavy vehicles are usually either social, such as road safety campaigns or safety management programs, or technical, such as central barriers on motorways or driver-assistance technology (e.g., Phillips et al., 2011; Soccolich et al., 2013; Bengler et al., 2014; Naevestad et al., 2018; Faus et al., 2021). *Sociotechnical* measures are less common, even though such measures could account for important risks arising from interactions among social and technical factors (Young & Salmon, 2015).

Sociotechnical measures can be identified using methods derived from sociotechnical systems theory (Read et al., 2017). This theory embodies a system approach, and describes how people operate in open systems comprising social and technical elements that interact to create emergent properties and conditions that influence valued outcomes negatively or positively. In the current report, we explore the idea that sociotechnical measures are needed to prevent drivers of heavy vehicles from being distracted and to help reduce the number of collisions in which they are involved. We do this by developing ideas for sociotechnical measures against mobile phone use by bus drivers, using methods anchored in sociotechnical systems theory.

1.1. Distraction and Mobile Phone Use by Bus Drivers

Mobile phone use is a main cause of driver distraction (Regan et al., 2011; ERSO, 2018), causing slower reaction times, more erratic steering, and increased lane deviation (Caird et al., 2008; Papadakaki et al., 2016). An increased risk from mobile phone use is largely unavoidable when it causes visual distraction or where drivers drive through complex environments (Oviedo-Trespalacios et al., 2016). The level of distraction depends on the mode of use (visual, auditory etc.) and the content of communications; hands-free phones are not necessarily less distracting than handheld phones (Lipovac et al., 2017). A study of over 13,000 professional drivers in the USA found that the likelihood of being involved in a safety-critical incident increased by 23 times if the driver texted or "surfed" on a mobile phone while driving (Olson et al., 2009). Mobile phone use has also been implied in 1 in 40 near misses or accidents involving bus drivers in Norway (Moe, 2006).

Results from several studies suggest that use of a mobile phone while driving is more common among professional drivers than private drivers (Troglauer et al., 2006; Brusque & Alauzet, 2008; Young et al., 2010; ERSO, 2018) and that such use can be extensive (e.g. Olapoju, 2016; Iseland et al., 2018; Rosso et al., 2018). Reasons for this include the need to carry out essential work tasks while driving (Bruyas & Evennou, 2018); a need to use their phone to communicate with colleagues, friends, and family; and relief from strain or boredom due to more hours at the wheel (Durgamani et al., 2018). Other studies indicate that more time spent at the wheel could cause professional drivers to become overconfident in their ability to drive safely while using a mobile phone (e.g. Choudhary & Velaga, 2019). Distorted beliefs might also be associated with increased phone use by professional drivers while driving (Valero-Mora et al., 2021).

1.2. Bus Drivers Must Find Workarounds in Day-to-Day Operations

Faced with increasing responsibility for the management of outcomes related to productivity, customer service, safety, and the environment, transport companies implicitly ask their drivers to resolve conflicting goals as they drive in complex real-world traffic (e.g. WHO, 2011; Phillips & Bjørnskau, 2013; Phillips, 2014; Newnam et al., 2017). In our studies, bus drivers often told us how they have to accept too many prams or bikes on board to avoid stranding passengers in the rain; or drive slightly too fast to help their company avoid a punctuality fine (Krogstad et al., 2019). It is not unusual for professional drivers to find workarounds like these when faced by goal conflicts, as ways of adapting to situations that threaten company goals (Alter, 2014).

1.3. Accounting for the Social Contexts of Technology

Rapidly evolving technologies are being introduced into the operational ecosystems surrounding bus drivers and unforeseen problems can result. For example, mobile phone use by passengers reduces bus driver attention (Salmon et al., 2011); drivers' own technology use habits can cause poor sleep and fatigued driving (Phillips et al., 2017); and displays informing drivers about the time to the next bus stop can cause them to speed up (Krogstad et al., 2019). Drivers also use technology in ways developers did not foresee to adapt to job demands (Woods and Hollnagel, 2006). The safe introduction of new technology requires the joint optimization of social and technological components, rather than optimization of components in isolation (Clegg, 2000). Authors concerned about the increasing complexity of modern transport systems have called for research to develop knowledge on such joint optimization using human-

centered systems engineering (Salmon et al., 2016; Newnam et al., 2017; Read et al., 2017). Doing so would help address the limited ways in which traditional occupational risk management accounts for increasing use of technology across work and home life and the influences this has on system outcomes such as safety (Swuste et al., 2014).

1.4. Human-Centered Systems Engineering

Approaches to human-centered systems engineering include sociotechnical systems engineering (Baxter & Sommerville, 2011), cognitive systems engineering (Militello et al., 2010), and human factors engineering (Stanton et al., 2013). Cognitive systems engineering emphasizes that to understand why people behave as they do in work systems, we should study how they can adapt and use technical components and social resources around them in creative and often unforeseen ways to perform system functions that conserve the achievement of valued goals (Woods and Hollnagel, 2006). Human factors engineering emphasizes people's cognitive and physiological limits, and the tasks in the work system surrounding the operator (Salmon et al., 2011). Sociotechnical systems engineering, on the other hand, emphasizes democratic job design values, and the need to account for broader social and technical influences in open work systems (Davis et al., 2014).

Despite some differences, each of these approaches differs from traditional risk management approaches by recognizing the need to understand how system outcomes are affected by interactions among social and technical factors in complex systems. In contrast, many risk management approaches often seek to *reduce* risk causation (e.g., mobile phone use) to single system components (e.g., driver error), root causes, or linear causal chains (Swuste et al., 2014; Woods et al., 2016). While risk management approaches can result in measures that prevent accidents occurring or propagating, several authors have emphasized the need to add methods that can generate measures to account for how system outcomes are affected by the sociotechnical complexity, openness, and interconnectedness of modern work systems (e.g., Leveson, 2011; Davis et al., 2014; Woods et al., 2016). Given its suitability for a broad initial analysis and assessment of influential factors in the open systems in which people operate, sociotechnical systems engineering provides a "user-friendly" way for practitioners to start studying the utility of such methods.

Sociotechnical systems is a paradigm with its own theory, methods, and design principles (Trist & Bamforth, 1951; Clegg, 2000; Fischer & Baskerville, 2020). According to the theory, work systems are open to the influence of surrounding systems and comprise social and technical elements that interact to influence valued system outcomes (Read et al., 2017). Sociotechnical systems theory treats people as adaptable resources requiring the social and technological support they need to achieve their goals. Joint optimization of people and technology is central to sociotechnical systems thinking (Read et al., 2017).

Sociotechnical systems methods are designed to elicit influences on system outcomes that result from interacting human, procedural, intentional, technological, cultural, and infrastructural factors existing in local "ecosystems" in which workers operate (Davis et al., 2014). These methods contrast with reductionist methods, which might seek to focus on human characteristics causing mobile phone use (e.g., Chen, 2007). Examples of sociotechnical systems methods are PreMiSTS (Clegg et al., 2017), systems scenarios (Challenger & Clegg, 2011; Hughes et al., 2017), or the sociotechnical systems framework (Challenger & Clegg, 2011; Davis et al., 2014; Clegg et al., 2017). The latter structures the identification of explicit combinatorial influences among six factor types, including three social or "soft" types—roles, goals, and cultural factors—and three technical/structural or "hard" types—technological, procedural, and infrastructural factors. Understanding how system components in each of the six dimensions are likely to interact and influence each other and desired system outcomes can lead to useful ideas about system improvement using sociotechnical measures—that is, measures suggested by analyses of work systems using sociotechnical systems methods (Challenger & Clegg, 2011).

1.5. Studying Mobile Phone Use While Driving

Mobile phone use has been studied using objective measures including roadside surveys, naturalistic studies, or data from mobile phone companies (Sagberg & Sundfør, 2016). Interviews and self-report surveys about what drivers themselves say about mobile use while driving are an important complement to these methods. There are many individual and organizational factors that can influence mobile phone use by bus drivers, and several theoretical models of behavioral change have been used to structure them (e.g., NCRS, 2017; Adeyemi, 2021). Of individual factors, anxiety caused by being without a mobile phone ("nomophobia") may be important (e.g., Kaviani et al., 2020). More recently, however, authors have demonstrated using Rasmussen's (1997) risk management framework that reductionist driver-centric approaches

to the development of measures against driver distraction are by themselves insufficient, and should be supplemented by *systems* approaches that can account for influential factors in the operational ecosystems of drivers (Young & Salmon, 2015; Parnell et al., 2016). Several studies are now available showing how systemic factors, such as the use of other technology, legislation, or job crafting, can influence mobile phone use while driving (Parnell et al., 2016, 2017; Costantini et al., 2022). More studies are needed, though, to analyze how factors in the sociotechnical ecosystems of heavy vehicle drivers can influence their mobile phone use.

1.6. Study Background and Aim

Our aim in the present study was to assess the extent to which analysis using the sociotechnical framework could inform the development of a new class of measures with the potential to reduce collisions risks, by accounting for factors in operational ecosystems interacting to support mobile phone use by bus drivers. The sociotechnical framework was chosen as it helps demonstrate to organizations the importance of accounting for sociotechnical factors in a way that is easy to understand. To learn about the extent of the problem and mobile phone use habits, we also asked bus drivers to participate in an on-line survey.

2. Method

2.1. Case Description

The case involved bus drivers working for a large bus company in Norway, operating lines for a regional administrator that discouraged *any* form of mobile phone use by bus drivers while driving, and issuing charges to contracted companies whose drivers were observed using the phone. Note that at the time of the study, Norwegian law forbade the use of a handheld phone while driving. Leading up to the study, the number of customer complaints to the administrator about bus driver mobile phone use had increased by 58% over a 12-month period. As a result of these complaints, the company reminded drivers regularly that any form of mobile use while driving was not allowed. This restriction was also stated in contracts and in driver handbooks issued by the company. At the company, an operations manager is responsible for all bus drivers working within a regional area, and drivers are organized in several driver groups each with ~150 drivers and a group leader. Drivers have contact with a traffic controller while driving; these are responsible for communicating with drivers and coordinating movements and issues arising in traffic.

2.2. Questionnaire Survey

A survey on mobile phone use was sent to 1500 drivers working for the study company and a comparison company operating a similar mix of urban and urban/rural bus lines for the same administrator. Drivers working for the comparison company were surveyed to indicate extent to which the responses of study company drivers could be generalized. Following the survey, we conducted interviews in the study company to inform the sociotechnical analysis (see below). Surveys and interviews were conducted during the spring of 2018. The survey covered the following themes (Full Question Set provided in Appendix 1 of the Supplemental Material):

- driver background (experience as driver, full-/part-time position)
- frequency and context of mobile phone use while driving a bus
- whether drivers tend to have mobile phone with them and how they set their phone when driving a bus
- how often drivers check for messages while driving a bus
- perceived detection and accident risk when using a mobile while driving
- perceived level of mobile phone use by colleagues (descriptive norm)
- familiarity with company policy and its communication.

A link to the survey was sent out to each driver's internal e-mail address via bus company management. Drivers were assured that only the researchers had access to individual responses, which were in any case anonymous and not traceable to them. Survey participants were informed that participation was voluntary and that they were free to withdraw from the study at any time.

Analysis. Data were assembled and cleaned, and simple statistical analyses were conducted on a single dataset using SPSS Statistics 24. We received responses from 33% of drivers from the study company and 40% from the comparison company. As a result of agreements with driver representatives, data on age and gender were not collected. The respondent sample was representative of bus drivers at the bus companies in terms of length of experience. All drivers drove between three and six days a week on average. Most drivers (over 90%) at the company were male, which is typical for the bus driver population in Norway.

2.3. Interviews

We conducted interviews at the study company garage on two separate visits. At the first visit, we conducted a two-hour focus group interview with 10 people comprising an operational manager, three driver group managers, a driver trainer, and five driver representatives. All participants were male, and the mean age was between 45 and 50 years. The aim of the interview was to understand the organization and to identify themes for discussion with drivers that would most effectively generate data for the sociotechnical framework (Davis et al., 2014). Following this meeting, the identified themes were tested and developed in pilot interviews with three bus drivers. This resulted in the semi-structured interview scheme shown in the box below:

Short description of project, which aims to understand mobile use while driving a bus. Emphasize anonymity and that bus drivers themselves may have the most useful views on how companies can help reduce mobile use while driving.

1. Do you sometimes use mobile phone while driving bus, for dialogue, texting, music, social media, other apps?
   If no: Can you explain what influences you not to use your mobile? Do you ever see colleagues or drivers from other companies using a mobile while driving? Why do you think some bus drivers use mobile phones while driving?
   If yes: When do you use it? What do you use it for?
2. What do you know about the consequences of using mobile phone while driving?
3. What makes you use the mobile phone anyway? OR is it these or other consequences that stop you using the mobile while driving?
4. How do management communicate about mobile phone use?
5. What could be done to reduce mobile phone use by drivers?

This scheme was used to structure dialogue with drivers and group leaders at a second visit to the garage, in which a researcher and a driver representative spent the day recruiting drivers opportunistically from the garage's main break room. Interviews were conducted with groups of between one and four drivers at a time, in the presence of the representative. Drivers interviewed together were well-acquainted. Twenty-six drivers were interviewed across nine interviews, each interview lasting up to 40 minutes. Drivers were assured of anonymity and that participation was voluntary. All drivers interviewed were male and the mean age was between 40 and 45. All age groups from 25–30 to 60–65 years old were represented with at least one interviewee. Detailed notes were taken, with consent obtained beforehand. Consolidated criteria for reporting of qualitative studies is provided for the interviews in Appendix 2 of the Supplemental Material (COREQ; Tong et al., 2007). All surveys and interview procedures were reviewed independently and found to be in line with the institute's ethical research policy.

2.4. Mapping of Sociotechnical Factors

Notes from focus groups and interviews with leaders and drivers were analyzed to map factors in the sociotechnical system surrounding bus drivers. This was done in two "passes": 1) Factors mentioned in connection with drivers' mobile phone use were identified, and similar factors were consolidated and used to populate the sociotechnical framework by arranging them under the following categories: People, Goals, Culture, Technology, Infrastructure, or Procedure (Davis et al., 2014; Hughes et al., 2017); 2) The interview notes were analyzed again, to identify interactions between factors that influence mobile phone use while driving. Interactions were then arranged under four superordinate themes that we believed captured prevalent combinations of factors, as described in the Results.

3. Results

3.1. Survey Findings on Mobile Phone Use

Around 20% of drivers reported using a phone while driving at least sometimes (see Table 1), at both the study and comparison companies.

Drivers who answered that they used the mobile phone at least sometimes while driving were then asked what they used it for, with most answering that they used it to answer a call from family and colleagues. Most (91%) drivers in the study company who said they never used a mobile phone while driving reported that they often or always took their phone with them on the bus, and very few drivers reported turning their mobile phone completely off as they drove (last row, Table 1). On average, respondents believed that half of bus drivers use a mobile phone at least once a week while driving. Most drivers in the study company (93%) reported that they were familiar with company policy forbidding any form of mobile phone use, and 76% of drivers reported that they had received information from the company about mobile phone use while driving within the past three months. We found no indications that those who used mobile phones more often were any less familiar with policy or received less information.

3.2. Sociotechnical Systems Analysis

The sociotechnical system was defined as the *goals, people, infrastructure, technology, culture, and processes influencing bus drivers' use of mobile phone while driving.*

Table 1. Share (%) of bus drivers from study and comparison companies answering different questions on mobile phone use while driving (*n* indicates the number answering each question).

	Study company	Comparison company	Total
Of all drivers responding:	(*n* = 245)	(*n* = 331)	(*n* = 576)
How often do you use your mobile phone while you are driving the bus?			
At least once a day	4%	5%	5%
Once to several times a week	3%	5%	4%
Sometimes but less than once a week	13%	12%	12%
Never	80%	79%	79%
	(*n* = 46)	(*n* = 69)	(*n* = 115)
Of those who say they use their phone to some extent while driving:			
What do you use the telephone for?			
Make a call	16%	18%	17%
Answer a call	56%	63%	60%
Send SMS or other message	4%	3%	3%
Check for messages	25%	20%	22%
Listen to music	36%	30%	32%
Use of other apps	12%	4%	7%
	(*n* = 28)	(*n* = 49)	(*n* = 77)
Of those who make or answer calls while driving:			
Who do you speak with most while driving?			
Family	39%	41%	40%
Friends	4%	6%	5%
Colleagues	32%	27%	29%
Others	25%	27%	26%
	(*n* = 166)	(*n* = 115)	(*n* = 281)
Of all driver respondents who take their phone with them but do not use it:			
Which mode do you usually use while driving the bus?			
Sound or vibration is on, and I can hear incoming calls and messages	43%	36%	40%
Sound or vibration is on, but I do not hear calls and messages	17%	20%	18%
On silent (no vibration)	37%	40%	38%
Turned completely off before driving	3%	4%	3%

From analysis of interview notes, we agreed on four superordinate themes describing how components in the ecosystem interact and influence bus drivers' use of mobile phone while driving. These are described subsequently using the comments of interviewees.

Technology in Society

Mobile phones have replaced landline phones at home and at work, they offer many ways to communicate (written, oral, one-to-one, social media, etc.), and have become the main communication tool in society. Not surprisingly, mobile technology and wearables increasingly permeate both society and organizations. It is not uncommon for drivers to see other road users using their phones, including some other bus drivers. A few drivers commented that leaders had also been seen using phones while driving. Some drivers commented that people use phones while driving due to the positive feelings they experience when they receive a message or other communication via mobile phone. One driver pointed out, "it's normal to look at the mobile when you're alone—the mobile is always to hand." Several of the drivers interviewed said they often have family, friends, and others who call or send messages, and the mobile technology itself will also attempt to communicate with the driver using automatic prompts and notifications.

Company managers accepted that mobile phones are a "good friend" for bus drivers, who often face lengthy periods waiting alone at bus stops and terminals. Managers also considered mobile phones as an important means of communicating in critical situations where drivers must leave their on-board radios. Drivers provided several important reasons why they needed to have their phones with them, including a need to use their phones for work (e.g., to clock-in using the phone when they start work or to receive text messages from the company). Some of the company messages required rapid response, such as "first come, first served" requests for drivers to work overtime for which drivers receive extra pay.

Bus Driver Culture

Most of the more experienced drivers and managers commented on a change in bus driver culture that supported mobile phone use while driving. The drivers sensed reduced cohesiveness among drivers at the garage, particularly in the break room and three main reasons were given for this. First, whereas persons seeking employment today are often encouraged to qualify as bus drivers, and can receive welfare support to subsidize their education, the more experienced drivers had been intrinsically motivated to work as bus drivers and had invested their own funds in their education. As a result of this, some experienced drivers felt that newer drivers

had a reduced sense of occupational pride, and that this made them less inclined to avoid using the mobile while driving. A second reason was that on recruitment and arrival at the garage, drivers from different countries became poorly integrated with existing drivers, with many new drivers tending to stick with drivers with similar backgrounds or with drivers who shared their native language. Some drivers had the sense that, over time, closed driver groups had developed at the garage. A third reason for reduced cohesiveness was that fewer drivers than before used the break room, especially following a shift, due to increasing time pressure from schedules. Being less able to identify with colleagues, drivers also noted a tendency to seek social connection with family/friends or entertainment through use of their mobile phone instead. Growing dependence on the mobile phone could then again increase the psychological distance between drivers.

Conflicting Goals

According to responses, bus drivers have three conflicting work goals: traffic safety, customer service, and punctuality. As part of operations, group leaders or traffic leaders from the bus company can contact the drivers via radio or send text messages via mobile phone. Drivers can also be asked via radio to use their mobile phones to contact someone at the company later during a shift. Other occasions demand that drivers check or answer their phone; for example, if radio equipment is not working properly and they need to report delays or that they have driven past people waiting at bus stops because the bus is full. While drivers can wait to use their phones at bus stops, they indicated that this could cause delays and cause the bus company to be charged by the administrator for poor punctuality. Drivers also feel that passengers will become frustrated if they use their mobile at the bus stop, especially if they are trying to reach a train or ferry that is due to depart. In such situations, drivers can use their phone as they drive to in an attempt to meet the needs of passengers, their employer, and the administrator (i.e., as a way of prioritizing customer service and punctuality). Drivers do not necessarily experience that use of the phone while driving comes at the cost of safety. For the driver, mobile phone use is one of many "workarounds" that they must find and implement in order to achieve conflicting goals and do their job in the real world.

Inadequate Control

The ban against any form of mobile phone use while driving was written in the employment contract, via text messages from the company (ironically), and displayed on TV monitors on the walls of the break room. In line with this, all drivers interviewed noted they received the message that "drivers shall not use any form of mobile phone while driving" and they shall not have "anything in their ears." Effective control, however, requires that managers monitor the effects of this message on driver behavior and take further action as necessary, but drivers did not believe that mobile phone use while driving was monitored systematically or had consequences. They felt that phone use was rarely reported, and that the consequences were not always serious even if it was reported. Several interviewees therefore wondered if drivers took the mobile phone message seriously. One manager pointed out that the administrator charged the bus company ~500 Euros for a valid customer complaint received about a driver using a mobile phone while driving; but the driver received no charge. While drivers can receive a formal warning from the company for mobile phone use, three formal warnings must be issued before they risk punitive action. While they can receive a small charge from the police for hand-held use of mobile phone, drivers perceived their risk of discovery as small. Thus, it seems that processes controlling mobile phone use at the company were incomplete: while the company communicated the message about forbidden mobile phone use effectively, they did not make the negative consequences of mobile phone use visible to drivers. A lack of visible consequences may also have acted indirectly to support mobile phone use while driving.

Summary of Sociotechnical Interactions Supporting Mobile Phone Use

The main interaction streams among the sociotechnical components described by interviewees are summarized under four themes in Figure 1. Although Figure 1 illustrates direct influences supporting mobile phone use, multiple indirect interactions among sociotechnical factors within and across each of the six dimensions were also evident in interview responses (this is illustrated by the dotted lines in the Figure, after Davis et al., 2014). Potentially important interactions among all six dimensions should be borne in mind when developing measures to reduce mobile phone use by bus drivers.

4. Discussion

Our survey results confirm that mobile phones could be a serious distraction for many drivers operating a bus, implying that measures are needed to prevent mobile phone use by these drivers. One in five bus drivers

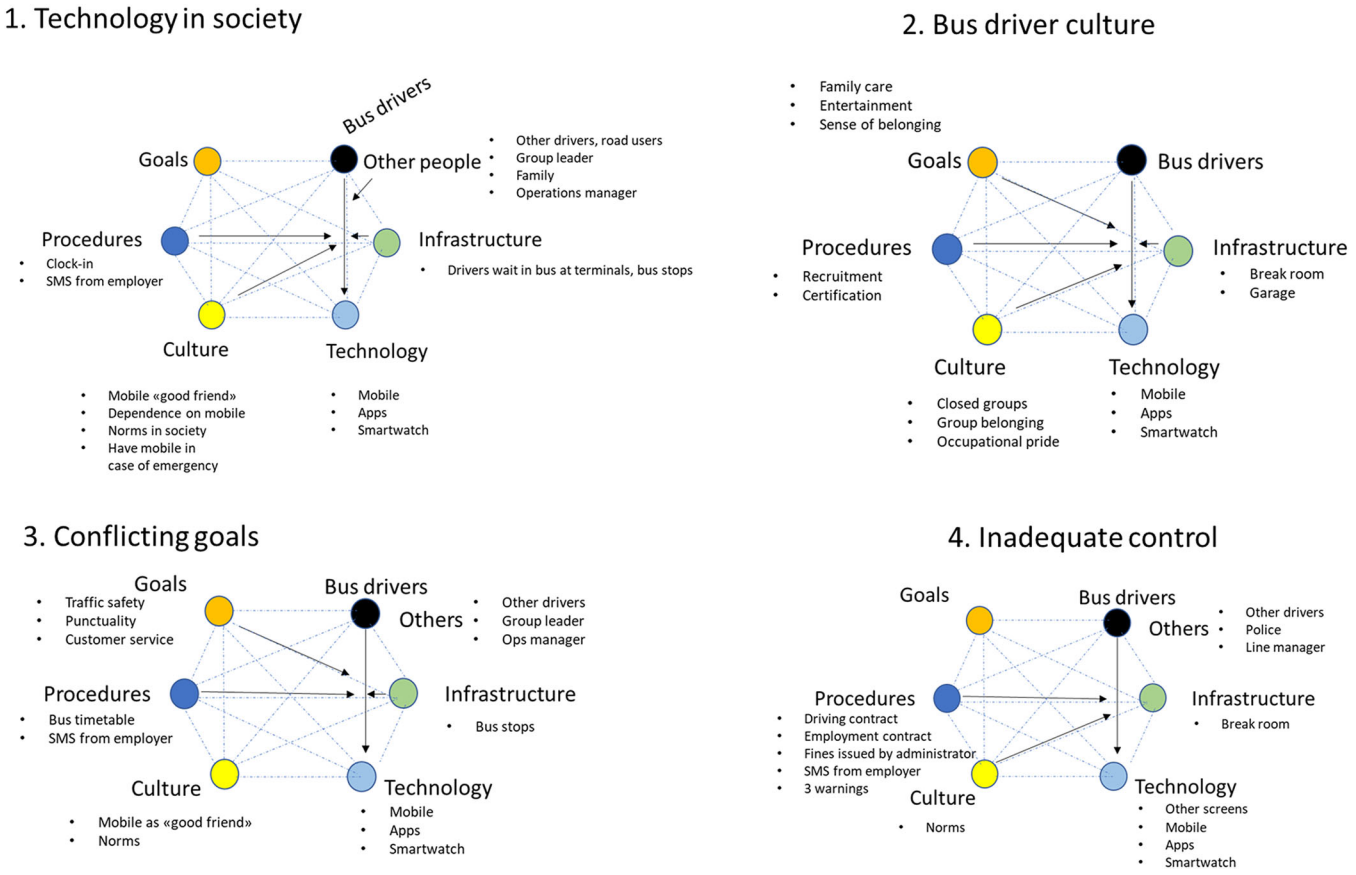

Figure 1. Main themes describing sociotechnical interactions supporting the use of technology (mobile phones) by bus drivers while driving.

across two different bus companies reported using a phone at least sometimes while driving, and almost all drivers indicating having a mobile phone with them whether or not they used it. Many drivers who did not use a mobile phone while driving could still hear incoming calls and messages from friends, family, or managers. These results are in line with previous studies finding suggesting extensive distraction of professional drivers due to mobile phones (e.g., Rosso et al., 2018). Given that the relative risk of being involved in a fatal road accident is 9.3 times higher for drivers using a mobile while driving, and that distracted drivers are involved in 12–14% of fatal accidents, such results should be a cause for concern (Elvik, 2020). This is particularly so given that professional drivers of heavy vehicles are overrepresented in serious road accidents, being involved collisions that are responsible for one-third of road fatalities (Langeland & Phillips, 2016), with buses and coaches being involved in up to collisions responsible for up to 1 in 20 road fatalities (ERSO, 2021).

Analysis of interviews with bus drivers and managers suggests four main ways in which factors interact across sociotechnical dimensions to support mobile phone use by bus drivers. First, bus company managers, drivers, and the outcomes they control are influenced in unforeseen ways by rapid technological developments in society, in which people in and outside of work rely on mobile phones and apps for communication "anytime, anywhere." Second, both managers and drivers accepted that mobile phones can help drivers manage a reduced sense of belonging and emergency situations as lone workers. Third, we found that the mobile phone is a useful tool that bus drivers can use to help them find workarounds to manage conflicting goals of traffic safety, punctuality, customer service, or family support. Fourth, while drivers were aware of messages that mobile phone use while driving was not allowed, there was little done to enforce this rule using people, technology, or other means, such that drivers did not perceive the consequences as serious. A perceived lack of consequences may encourage mobile use when combined with manager and driver cultural norms for continual mobile phone utilization and high descriptive norms for mobile use while driving.

Together, these results suggest that several different types of sociotechnical factors spanning work and life outside work combine to support mobile phone use

by drivers. By implication, measures derived from reductionist analyses of mobile phone use, such as those accounting for human error (e.g. Chen, 2007) or task dynamics in the immediate operational system (e.g. Salmon et al., 2011), will fail to capture all important risk causes occurring in naturalistic work systems. Furthermore, occupational risk management rooted in reductionist analyses may inadequately manage the risks. Using an example from our study, fining drivers using mobile phones, as one manager in our study wanted to do, may not succeed while a) mechanisms for control and follow-up are inadequate and b) managers counter the financial drawbacks of fines with the promise of overtime to those who reach their phones first. Likewise, while campaign effects can be improved by complementary measures such as driver education programs or sanctions (Faus et al., 2021), isolated attempts to improve knowledge or change attitudes of bus drivers may fail to succeed as long as the mobile phone affords drivers a way to manage pressing family situations or reduce monotony while at work. Fines, campaigns, and similar measures may also be undermined if managers perceive that the mobile phone is a useful and effective tool for the drivers to have with them as a back-up communication tool or for carrying out work tasks when radios fail. In concrete terms, they would fail to account for three of the four ways in which different sociotechnical factors combined to support mobile phone use by bus drivers in our study company. Our results therefore support the need for human-centered systems approaches to identify complementary measures as part of occupational safety management.

Although several of the causal factors reported here have been reported previously—most notably that the use of a mobile phone is supported by a need to carry out work tasks while driving (Bruyas & Evennou, 2018) and the lack of opportunity to communicate with friends or family (Durgamani et al., 2018)—we believe our study is the first to demonstrate the interactive and comprehensive nature of sociotechnical influences on mobile phone use by bus drivers. This was achieved using relatively simple analyses, which could also serve as the basis for sociotechnical measures.

Figure 1 presented four heuristics that could inform the design of sociotechnical measures at the company studied. We illustrate how this could be done by describing an analysis of the first two heuristics in Figure 1. Looking at "Technology in society" first, we see that **Culture** (social norms, societal acceptance of and dependence on the mobile phone) is manifest in the attempts of **Other people** (managers, colleagues, friends and family) to contact drivers while they are driving. The use of mobile phone by drivers is further supported by **Procedures,** which ask drivers clock-in or learn about overtime via their mobiles, and **Infrastructure**, which is constructed such that drivers wait alone at stops and terminals with no other form of communication than a mobile phone. While changing **Culture** or **Other people**'s behavior is difficult, management **Procedures** could be changed quite easily, for example by asking drivers to come into the depot to receive messages about overtime, rather than receiving them by phone. Changes to the depot (**Infrastructure**) might also be considered to make visits more appealing, or **Procedures** could also be addressed to formalize regular depot visits.

Looking at the heuristic for "Bus driver culture" in Figure 1, we can also find ways that managers could reduce the psychological distance between driver groups, to give drivers an increased sense of belonging and reduce dependency on mobile phones. In this case, the heuristic shows how mobile use can be supported by drivers' prioritization of non-work related **Goals** (caring for family, entertainment, sense of belonging). It shows how recruitment **Procedures** can select for drivers with reduced occupational pride and who may be more isolated in Norwegian society, who may therefore tend more to disregard instructions on mobile use while driving. "Garage" **Culture** is one involving a reduced sense of occupational pride among younger drivers, and closed driver groups supported by **Infrastructure** in the form of small tables with room for 5–6 people in garage break room. In designing of sociotechnical measures, for example, smaller tables could be replaced by one large table, recruitment procedures could select for candidates with a high sense of occupational pride, the importance of safety goals in relation to mobile phone use could be emphasized, or families and friends could be given alternative ways to contact bus drivers during the day. Similar analyses could be done for the heuristics "Conflicting goals" and "Inadequate control".

The implications of our findings on sociotechnical influences can only stand if our study can be shown to be valid, reliable and practically useful. Addressing validity, a strong advantage of our approach has been an emphasis on real operations. On the other hand, opportunistic sampling of drivers in the break room at the company garage limited the extent to which we can say that the findings were representative of all company drivers. While we interviewed drivers representing different group types, the views of drivers who tend not to use the break room will have been less

represented in the interviews, possibly affecting how the sociotechnical framework was populated. While use of the approach in other projects leads us to conclude that analysis of notes and population of the framework is reliable, inter-rater reliability for the sociotechnical framework has not been quantified or published, and future work should address this.

Survey response rates were relatively high for contemporary surveys, but we cannot rule out that answers were not affected by differences between responding and non-responding drivers. Constraints placed on our ability to collect data on demographics in the questionnaire survey limited the extent to which we can assert that our survey results are generalizable, but those demographics we did obtain (experience and days worked per week) indicated the responding drivers were representative of the company and the wider bus driver population.

Concerning practical usefulness, we know that some suggestions from the project (e.g., longer tables in rest rooms to encourage group mixing) were appealing to managers and were acted on. The administrator, who did not sponsor but was consulted in the study, has also taken steps to focus more on traffic safety in its contracts with companies. Despite this validation, true sociotechnical measures can only be identified and developed by involving stakeholders engaged in and influencing real operations (Davis et al., 2014), preferably using human-centered engineering approaches (Militello et al., 2010). Finally, replicating this work in other situations and countries would be compelling, and validate the need to account for sociotechnical factors supporting mobile phone use by professional drivers.

5. Conclusions

A survey of drivers at two bus companies in Norway suggests that 20% of drivers use a mobile phone while driving at least sometimes, even though it is not permitted, confirming a need to understand and address bus driver noncompliance. An analysis of the sociotechnical system surrounding drivers at one of the companies suggested four ways that sociotechnical factors combine to support their mobile phone use, describing: (1) society's increased dependence on technology; (2) developments in bus driver culture; (3) a need to resolve conflicting goals; and (4) lack of belief in adverse consequences of using mobile phone while driving. Our findings support claims that driver-centred, reductionist analyses of mobile phone use or other traffic safety challenges are insufficient for measure development, and that they should be supplemented by sociotechnical analyses. We demonstrate how analyses using sociotechnical methods can produce heuristics to inform the design of sociotechnical measures and help reduce road safety risks. Researchers and practitioners should utilize such analyses and attempt to realize the potential of sociotechnical measures using human-centered engineering approaches.

Conflict of Interest

The authors declare no relevant conflict of interest.

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ORCID

Ross O. Phillips http://orcid.org/0000-0001-6861-3549

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