Safety, autonomy, remote control and operations of industrial transport systems – (SAREPTA)

1. Relevance relative to the call for proposals

A safer and greener transport system is urgently needed. Further development of conventional technology will play a role in achieving this, but to reach the ultimate goals of zero accidents and full decarbonisation, new and revolutionary technologies are needed. Autonomy and fully or partly unmanned operation is one of the most promising candidates here[1]. In addition to accidents reduction, increased automation represents a major technology leap that is necessary to remodel the existing transport systems and shift transport to more energy efficient modes (Fagnant et al. 2015, Rødseth ed. 2015). There is thus every reason to believe that the smart, green and sustainable transport system will be characterized by autonomy. Autonomous transport is already being deployed in some transport modes and the rapid pace of technological and societal change creates a strong need for knowledge, standards and regulation that allows for exploiting the benefits of new technology, without running unacceptable risk.

The key objective in this project is to provide necessary knowledge for the development of improved methods for risk assessments and mitigation in transport systems that are autonomous, remotely controlled and/or periodically unmanned. This knowledge is not available today and it is critical both for cost and energy effective design of autonomous systems to be used in the industry and for testing and approving such systems for broader use in society.

Some of the major challenges for transport in Norway and Europe are high level of accidents, congestion and the need to reduce emissions. Autonomy has been identified as a major component to mitigate these challenges. Increased automation is likely to reduce accidents. However, there are several obstacles that need to be overcome in order to make full use of autonomous vehicles. The main problems are verifying safety/security and costs of safe development. Improved design, verification methods and regulations may remove much of these problems, but these cannot be developed before the basic knowledge of the risks has been established. No systematic documentation of risk levels was identified when we performed a review of safety and security of autonomous systems. In other words, the most basic prerequisite for effective risk management is missing, that is, a baseline description of the hazards involved in an activity. Without this knowledge, it will prove impossible to establish the risk based regulatory framework needed to ensure timely implementation of the beneficial aspects of autonomy.

The vision of the project is "E*nabling the transition to a green, smart, safe and secure autonomous transport system"*. We will contribute to this by building a scientific foundation that makes policies, decisions and public debates on autonomous systems knowledge-based rather than based on anecdotal evidence. The project addresses three of the thematic priority areas in Transport 2025: (1) Overall perspectives on the transport system, (2) Improved transport safety and security and (3) Future oriented infrastructure. The content in our project comprise:

A. **Risk identification and risk levels:** We need to systematize knowledge of the things that can go wrong. This involves research on accidents and successful recoveries, including observed and expected risk levels and a generalization between transport modes. The project will develop risk identification methods that can extend the mapping into uncharted risks.
B. **Infrastructure vulnerabilities and threats:** We need to understand the underlying vulnerabilities that allows things to go wrong. This involves analysis of requirements and vulnerabilities of communication, navigation and observation technologies that supports operational and situational awareness in the control of autonomous systems. This includes potential cyber security (and cyber physical) threats.
C. **Technical, human and operational barriers to mitigate autonomous system risks:** We need to create barriers that can prevent things from going wrong. This involves developing methods and approaches to improve safety, security, and resilience in autonomous systems. Contributing to the development of standards will be a key issue here.

[1] Connected and automated transport is a key technology in EU: https://ec.europa.eu/programmes/horizon2020/en/news/towards-strategic-transport-research-innovation-agenda-stria

D. **Organisational and human factors, as well as regulatory measures for risk mitigation:**We need to create a regulatory framework that allows for integrated overview of an integrated, tightly coupled transport system. This involves studies of organisational and regulatory issues and suggested measures to improve the overall risk governance of an autonomous transport system, including the capability to make knowledge-based decisions about where and how to keep "the human in the loop", in particular targeted to remote control and supervision centres as well as for other parties using the transport systems.

2. Aspects relating to the research project

Background and status of knowledge

The Norwegian transport authorities draft for National Transport Plan outlines rather ambitious goals regarding traffic safety, environmental impact of transport and living environment. It will be a tough challenge to achieve the goals by incremental technology developments. Therefor one or more paradigm shifts needs to be realized. One important paradigm shift will be the emerging autonomous vehicles and vessels. This project will mainly investigate autonomy in sea and road traffic. The focus is on industrial autonomous systems, i.e. larger systems used in commercial and public applications where cost-effective security and safety is a major concern. However, results can be applied in other areas and in other transport sectors.

Autonomous vehicles have been around since the 1980's[2], but research has typically been driven by academic, military or space applications and has not addressed the problems of operating autonomous vehicles in a public and commercial environment. Literature gives very few publications addressing the issue of risk assessment or risk levels for this type of operations. It is well known that these systems will be error-prone if not designed correctly[3]. Many accidents can be avoided as the possibility for human errors are eliminated and people are removed from danger (Rødseth & Tjora 2014; Burmeister et al 2014). However the risk level of autonomous systems are largely unknown, although one investigation documented a level of mishaps in unmanned aircraft systems 100 to 200 times that of manned aviation, (Waraich et al 2013). Due to poor systematic knowledge it is difficult to prioritize risk mitigating strategies and conditions unmanned vehicles can be allowed to operate in.

Sea. Autonomy is used to a limited extent in industrial maritime systems and mainly for specialised applications, typically military[4] or advanced underwater mapping[5]. There are, however, some concept studies and research activities on topics related to autonomous ships, including the EU FP7 project MUNIN[6] unmanned dry bulker, ReVolt[7] coastal ship and the AWAA project by Rolls Royce[8]. SeaTonomy[9] is an internal SINTEF project developing a methodology for industrial autonomous systems, including ships. A ship and its cargo are costly, and the ship has the potential to cause great damage to both the environment and surroundings, making risk control particularly important. Current ship operations are based on doing technical maintenance on board during voyage, which is not possible with unmanned ships. Technical reliability and failure management will be particularly important. Communication infrastructure is also a challenge and ships are generally dependent on (costly) satellite communication.

Road. Road autonomy is dominated by the emerging technology of cooperative ITS (C-ITS) and autonomous cars using sensors and advanced software to operate among normal cars. These technologies are also combined into truck or car platooning. Many research projects have developed and evaluated C-ITS for solving major transport challenges, including traveller services (TELEPAY, ROADIDEA), road and traffic managements systems (compass4D, FOTsis, COOPERS), safety systems (SAFESPOT, COMESafety), communications systems and architecture (CVIS, ITSSV6) and, technologies for improved energy efficiency

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[2] See e.g. CMU Navlab and ALV projects: http://www.cs.cmu.edu/afs/cs/project/alv/www/
[3] See e.g. http://www.washingtonpost.com/sf/investigative/2014/06/22/crashes-mount-as-military-flies-more-drones-in-u-s/
[4] http://gemini.no/2010/02/selvstyrte-roboter-til-sjos/
[5] https://www.km.kongsberg.com/ks/web/nokbg0240.nsf/AllWeb/D5682F98CBFBC05AC1257497002976E4?OpenDocument
[6] www.unmanned-ship.org
[7] https://www.dnvgl.com/technology-innovation/revolt/index.html
[8] http://www.rolls-royce.com/~/media/Files/R/Rolls-Royce/documents/customers/marine/voyaging-into-the-future-tcm92-55520.pdf
[9] http://www.sintef.no/home/projects/information-and-communication-technology-ict/seatonomy/

(eCoMOVE). It is believed the technical issues are or are on the way to being solved (Hess et al. 2014; Enei et al 2011). *Security issues* have become more in focus as significant vulnerabilities has emerged, and including awareness and policies to ensure that security is taken care of, ref Shi et al (2011). *Organisational issues* include organisational architecture; centralized control and surveillance; use of Human Factors knowledge in design of surveillance and stakeholder involvement and cooperation. The safety effects of C-ITS are assumed to be positive, as the possibility of driver error is minimized[10]. There are safety issues (and security issues), especially concerning autonomous vehicles, which are not clarified. California Department of Motor Vehicles began issuing permits for the testing of autonomous vehicles in September 2014. This pilot indicates negative effects as accidents by introducing such vehicles in normal traffic (BBC News 11. May 2015), reporting that four out of the 48 self-driving cars on public roads have been involved in accidents in the last eight months. Both firms Google and Delphi denied their vehicles had been at fault. The taxonomy, reporting and analysis of accidents need to be explored in a human factors perspective. In addition there is a need to examine and document successful use of autonomy, i.e. improved safety to ensure a holistic perspective and that resilience can be increased.

Air traffic. Unmanned aircrafts have been in use for some time and there are a large number of different types in use. Lately, the use of unmanned aerial vehicles has been in rapid expansion. In Germany, drones have been used to deliver daily medication in remote areas, and this technology is coming to Norway. In the US, Amazon.com has started to distribute parcels through the use of drones. Few analysis of incidents and successful recoveries can be found. There is a need to systematize and establish taxonomies related to accidents and incidents during unmanned operations. There is a need to establish guidelines (such as human factors guidelines) and regulatory framework conditions to ensure that safety and resilience is proactively maintained when further developing this form of transport. Also in this area is there a distinctive lack of literature investigating the more general safety and security of such systems.

Railway/Subway systems. Unmanned subway and train systems are being used to transport people. Driverless and unmanned trains are usually operated by a sophisticated computer system located in a remote control room. The London Underground Victoria line, from 1967, was the first line operated with Automatic train operation (ATO). Many lines have now implemented some form of ATO, with the aim of improving the quality of service. ATO technology enables trains to operate without a driver: either with an attendant roaming within the train, or with no staff on board. The grade of automation is different, and there is a specification of the different levels in the standard IEC 62290-1.

Research gap. While this brief account of previous and on-going research related to autonomous systems hardly does justice to the details of the status of knowledge, it illustrates that the primary challenge to be addressed is the lack of knowledge. Moreover, the knowledge that exists is to a large extent fragmented and in need of systematization. The main ambition of SAREPTA is to contribute to systematizing and expanding the knowledge related to risk level, vulnerabilities, possible barriers and the need for novel, more integrated, regulatory approaches.

Approaches, hypotheses and choice of method

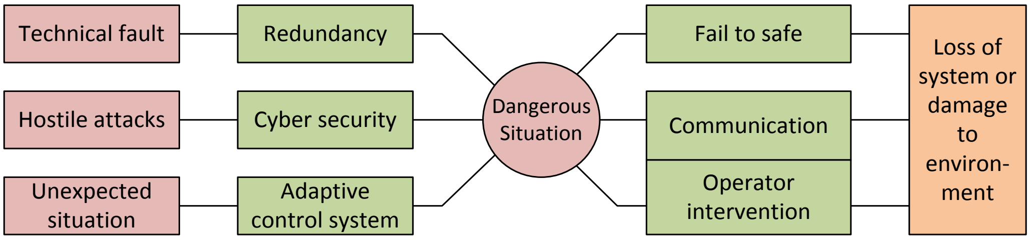
The transport system is becoming more tightly coupled as autonomous systems are implemented, creating "Normal Accidents" as described by Perrow (1984). Challenges of the new technologies are creation of new risk patterns and vulnerabilities, including communication (SafeCop 2016). Further, new failure modes and accidents will be caused by the vehicle's increased reliance on deterministic infrastructure, such as communication and design of supporting infrastructure and the possibility of a "Human in the Loop" i.e. human factor issues (Porathe, 2014). Some of the main groups of events that may cause risks for autonomous vehicles are:

- Technical malfunctions that impact the vehicle's ability to control itself; Sensor and object detection failures implying to overlook nearby objects; Control system failures causing wrong actions; Communication system failures causing remote operators to loose contact with the vehicle.
- Hostile attacks and cyber security/threats on control systems, communication or remote control centres.
- Unexpected situations in the vehicle or the environment that cannot be handled by the system and creates need for resilient design/solutions in control centres/facilities. Poor design of interaction

[10] EU (2012): Road Safety Newsletter nº 8, European Commission, Brussels.

between the system and the (remote) supervision or control centre can lead to human failures. Inefficient or improper monitoring and emergency processing intervention.

A bow tie diagram (as shown below) illustrates how different barriers can contribute to avoid catastrophic outcomes. Problems may be handled either by prevention (green boxes to the left) or corrective actions (green boxes to the right). Only if all barriers are bypassed will the negative consequence occur. However, the diagram does not reflect the full complexity of risk management for autonomous vehicles. The project will use two cases, one from road and one from sea, while using accident data from other transport modes, to develop improved statistical data and methods for risk identification, risk assessment and analysis of effects of different abatement approaches.



The main challenges in the project are:

A. Risks identification and risk levels. Because autonomous vehicles operating in real world situations are mostly unexplored, it may be difficult to foresee all relevant risks. New methods are needed for identifying possible risks and the possibility of resilience. The main challenge is to efficiently identify all relevant operational risks in a Man, Technology, Organizational (MTO) framework (Rollenhagen, 1995), and at the same time make it manageable for the analyst. Risk levels are very difficult to determine due to lack of statistics in the relevant domains, thus descriptions and cases can also be used.

Hypothesis: The project will be able to provide a generalized understanding of risks and risk levels related to autonomous transport systems based on an integrated MTO understanding, making a much more quantitative approach to risk mitigation and operational limitations possible.

Method: This project will provide a systematic approach to risk identification in autonomous transport systems and develop methods for risk calculations in this context. To determine how different methods can be used or combined, different analysis of traffic, cause-consequence and successful risk will be used in combination with simulations and Bayesian belief networks. Risk identification methods (e.g. HAZOP, Failure Mode) already exist and have been applied to autonomous systems (Rødseth & Tjora 2014; Grøtli et al 2015; Harper et al. 2011; Alexander et al. 2009). Also more general work in system oriented safety analysis called STAMP (Leveson 2011) and resilience (Hollnagel et al., 2006) will be explored to ensure that we are sustaining an integrated MTO understanding.

B. Infrastructure vulnerabilities and threats. Remote control and interaction between central control units and decentralized/ autonomous systems are being developed in all transport modes. Even more integrated cyber-physical systems, where software meets physical systems and communication technology, create new challenges (Lee 2008). Further, cyber-security threats will increase due to these integration and more dependence on communication (Neuman, 2009) and the white paper NOU (2015:13).

Hypothesis: Development of new methods for identifying infrastructure vulnerability and threats will contribute to more safe and secure infrastructure for autonomous systems. These methods will have applicability to other modes than from where the statistics and experience were collected.

Method: This project will develop methods for analysing vulnerabilities of autonomous transport infrastructure (e.g. communication and navigation systems) and threats related to e.g. systematic attacks from “hostile actors”. Focus is both on hostile cyber security attacks and on more general failures of components or systems. For road this will be related to the development of international standards in the ITS area. Inter-vehicle communication and cyber security for the road sector in Europe is addressed through a number of ETSI and ISO standards[11]. A few articles on more general car and control system security exists (e.g.

[11] European Telecommunications Standards Institute – ERTSI: See http://www.etsi.org/technologies-clusters/technologies/intelligent-transport/

Koscher et al 2010). On sea, one will look at more conventional technology and how the criticality of these can be managed. In addition to work in the MUNIN project (e.g. Rødseth & Lee 2015), maritime cyber security is an active technical area in ISO, IEC and IMO.

C. Technical, human and operational barriers to mitigate autonomous system risks. Recently, there is more attention on system level thinking rather than component or operational analysis, perspectives including organisational issues (Rasmussen, 1997) and system concepts (Leveson, 2011). Barriers are closely related to Issue:(A) "Risk identification" and are also an under-researched subject. Results from research on (A) will also be used here. A main contribution to risk mitigation is to find an optimal trade-off between autonomy level/ complexity and operational procedure design, including the use of remote supervision and control centres (Grøtli et al 2015; Porathe et al 2014).

Hypothesis: It is possible to develop a general and transport mode independent method for task assignment between autonomous system and human controller. Furthermore, the method will be able to supply (semi-) quantitative risk data on the selected risks that the human controller is supposed to control.

Method: This project will study best practice in the area. Part of the assessment will need to reassess the operational procedures and how the work is divided between the transport vehicle and the remote monitoring and control centre. We will use Resilience Engineering on a systemic level to explore the strength of human improvisation with technical opportunities. Theory from Human Factors, i.e. physical ergonomics, cognitive factors and organizational factors (Karwowski, 2012) will be used as a basis.

D. Organisational and human factors, as well as regulatory measures for risk mitigation. The predominant engineering perspective has been to automate as much as possible, and minimise the human interaction. A balanced integration between Human factors (HF) and technology has been missing (Cummings, 2014; Ryan and Cummings, 2015) and the support of the resilient perspective has not been sufficiently prioritized (Hollnagel et al 2006). In this project, HF areas in design of remote control facilities will be one of the key elements, exploring HF methods (Stanton et al, 2013). This area has to be assessed in a much more fundamental manner than earlier. The HF concept should be redefined in the context of automation, making it more evident that an error is a symptom of system problems, being an effect rather than a cause (Dekker 2002).

Hypothesis: New knowledge of and methods for assessing human factors and development of guidelines for design of organisational solution, technology, cognitive demand/work processes, and physical ergonomics will support human strengths and contribute to a successful implementation of future autonomous systems.

Method: This project focuses on how to meet future challenges of implementing autonomous vehicles in the transport system. The project will explore how the implementation will influence the need for changes in regulation, standardisation, and work of the safety authority. The use of autonomous systems is assumed to create a need for centralized control and coordination. The focus on regulations, organisational issues and collaboration between the different actors and control centres has improved safety significantly in the oil and gas industry (Antonsen et al. 2007). More remote operations and remote monitoring in the oil and gas industry has led to implementation of new standards and guidelines that has been used in the industry (Johnsen, Ask & Røisli 2008), these experiences are going to be explored. A key issue to improve collaboration between the regulator, management and the workforce has been the use of the participatory action research (AR) approach (bottom up perspective) from (Greenwood and Levin, 2007). Action Research is going to be used in this project in collaboration between industry, researchers and regulators that participates in this project. We also launch the principles of stress-testing and fall-back/resilience as a basis for the analytical framework we set out to develop. Stress-testing methods were developed as a response to Fukushima nuclear disaster and are devised to assess how a system responds to extreme circumstances. This is of particular interest in autonomous systems. What are the fall-back systems when autonomy fails? A stress-test analyses how a system sustains a steady increase of strain and pressure, introduced by a simulated breakdown of safety functions – one after the other (cf. ENSREG, 2011) in addition/in combination with security issues. The idea is thus to explore and identify system vulnerabilities by simulated safety barrier challenges. We will apply this principle to the autonomous transport system, direct it towards the interplay between operator and the central control systems.

3. The project plan, project management, organisation and cooperation

The research team is multidisciplinary, consisting of researchers from both engineering science and social science. The team have relevant experience and publications in the areas essential to the proposal. The Norwegian participant consists of SINTEF and the Norwegian University of Science and Technology (NTNU). In addition we are collaborating with researchers from US (MiT and Duke), giving us access to a broad set of research traditions and supplying our field of practices. MARINTEK and Technology and Society (TS), represent SINTEF. *TS* participate in this project through the groups *Technology Management, Transport Research and Safety Research*. MARINTEK has a long tradition and has received support through government budget to initiate the Ocean Space Centre, and are also one of the founders of the NFAS forum (Norwegian Forum for Autonomous vessels) together with authorities and industry. The Ocean Space Centre will include support control of remote unmanned vehicles offshore and underwater. NTNU participates through two researchers. **Prof. T. Porathe** from the group Interaction Design at the Department of Product Design at NTNU, focusing on interaction design and human factors. Prof. T. Porathe will be responsible for the PhD candidate in collaboration with IDI/NTNU. In addition **Prof. Jingyue Li** from the Computer Science Department (IDI) at NTNU will participate in the work. He is a expert on verification and validation of dependability (safety, reliability, and security) focusing on car platoon, autonomous boats and robots.

The participation from SINTEF consists of researchers with experiences of autonomy/remote operations in transport - aviation/space transport, road transport, trains and shipping. **Stig O. Johnsen** (SINTEF) has a PhD from remote operation in the oil and gas industry, is involved by the National Academies of Sciences in the Committee on the Application of Real-Time Monitoring of Offshore Oil and Gas Operations; is the manager of the Norwegian Human Factors Network (HFC). **Trine M. Stene** (SINTEF) Will bring in extensive research experience been related to interdisciplinary projects involving transport, petroleum, spaceflight and onshore industry. **Kay Fjørtoft** (MARINTEK) holds a position as ESA Ambassador in maritime communications. He has participated in projects in transport and logistics, covering subjects like information handling, analysis, communication and emergency handling. **Ørnulf Jan Rødseth** (MARINTEK) has worked with autonomous systems and ship automation from 1990. He has been the coordinator of the MUNIN project; an EU study on unmanned merchant ships and is currently establishing the Norwegian Forum for Autonomous Ships (nfas.autonomous-ship.org). **Terje Moen** (SINTEF) BSc in the field of Electronics, senior advisor at SINTEF Transport Research since 1990. Areas of expertise: Research Methodology with emphasis on instrumentation, data acquisition and analysis. Advanced vehicle technology, driver assistance systems and cooperative intelligent transport systems (C-ITS). **Dr. Gunnar D. Jenssen (SINTEF)** is a Human Factors expert with a PhD in Transport Engineering, on Behavioral Adaptation and Safety Effects of Advanced Driver Assistance Systems and a MSc. in Psychology. As Senior Research Scientist at SINTEF Transport Research, since 1988 he has extended his PhD work to User Acceptance of completely autonomous vehicles and feasibility of autonomous winter maintenance at airports.

The international collaborators are from strong research centres in the US, represented by **Mary Cummings** (Autonometrics, Duke University, HAL and MiT) and **R. Waraich** (Smartronix). M. Cummings are involved in the Humans and automation Lab/HAL (see hal.pratt.duke.edu), and have been extensive involved in research adapting technology based on human factors issues. R. Waraich has been involved in accident investigations of unmanned Aircraft Systems..

The collaboration network is strong – we have established a transport research network, partly funded by the Norwegian Research Council for the period 2015 - 2018. SINTEF, MARINTEK, NTNU Social Research AS and Safetec manages the network, and the participants in the network are going to be involved in our research activities through workshops and discussions of findings, to explore and discuss our findings by different perspectives and ideas. Based on our proposal we have received strong support from authorities and industries. The common perception has been that autonomous systems will be a key part of future transport and that there is a strong need to establish a more systematic understanding of hazards and risks in order to establish design guidelines, testing regimes and regulations. Support has been received from

- **Authorities:** The Norwegian National Rail Administration, The Norwegian Coastal Administration, The Norwegian Maritime Authority, The Norwegian Public Roads Administration, Standard Norway, The Norwegian Space Centre, The Norwegian Mapping Authority.
- **Norwegian Industry and associations:** The Federation of Norwegian Industries, ITS –Norway, Q-Free, Kongsberg Automotive, Kongsberg Maritime AS, DNV GL AS.

The above listed partners will be involved in the project by participating through interviews (in-depth interviews in key areas), in Action Researched based workshops (to identify key issues, prioritize action, explore and discuss suggested methods) as well as reviewers of results from the project based on exploration and learning of the suggested solutions (results/ methods). They will receive some results in advance of publications, and thereby be in a good position of getting new science that also could be used in internal business, such as when working with new regulations and standards for autonomous systems.

Work packages

The time-line and relationship between the different work-packages are described in the following, based on initiation of the project in 2017, and finalizing the project in 2020. We have described the timing and how the different work-packages feed into each other with an overview followed by details in the WP's.

The basis of the project work are the funding plan from Forskningsrådet:

Year	**2017**		**2018**		**2019**		**2020**	
Funding in 1,000 NOK	2 470		2 470		2 470		1 500	
Project activities	H1	H2	H3	H4	H5	H6	H7	H8
WP1 (H1 to H5)	**Risk identification and risk levels**							
WP2 (H1 to H6)	**Infrastructure vulnerabilities and threats**							
WP3…(H1 to end H8)	**Technical, human and operational barriers to mitigate risks**							
WP4…(H1 to end H8)	**Organisational, human factors and regulatory measures**							
WP5b..(H5 to end H8)					**Verification and Validation**			
WP5a	**Publication and dissemination**							
WP6a	**Project Management(based on project management system) and steering committee**							
WP6b	**PhD candidate work**							

The on-going activities during the project period are WP5a-Publication and dissemination; WP6a-Project Management and WP6b-PhD work. The activities WP1 to WP5b are dependent, and builds upon each other. Starting with WP1 Risk Identification and WP2 Infrastructure vulnerabilities that creates a foundation for the work in WP4- Measures (Organisational, Human Factors, and Regulatory). The suggested measures must checked through the activity WP5b-Verification and Validation.

The project comprises of the following work packages (described with results):

Work packages (with description of objectives, deliverables and WP dependencies)	**Lead /Cost kNOK**
WP1: Risk identification and risk levels (Basis for W2 to Wp5) ***Objective***: Describe safety and security challenges related to autonomous, remotely controlled and normally not manned transport systems, taking care of the green perspective. This includes key topics for accidents/incidents and successful recoveries that can build and foster resilience and improve safety. We will use an interdisciplinary perspective. The key issue is to discuss different perspectives in the four transport modes, by collection of reports from accidents, interviews with core group, trying to identify paradigms within each sector. Tasks will be used to compare similarities and points of distinction to identify knowledge gaps and development/innovation needs in the transport system as a whole, i.e.: - Examine level of accidents and explore relevant individual cases related to autonomous systems in the four transport modes - Identification of common approaches in the modes, and identify possibilities of learning between the modes and how that learning can be sustained - Identification of effects of hazards and threats, and how to manage that in risk analysis **Deliverables**: 1. Review of existing and development of new knowledge/methodology for risk identification and risk analysis 2. Mode and case studies describing the findings from hazard and risk identification from the studies, including paradigms within each sector, and effects on the total intermodal risk levels	**SINTEF TS**

WP2: Infrastructure vulnerabilities and threats (Building on WP1 and giving input to WP3) ***Objective***: Explore infrastructure vulnerability and threats, identify and describe the need for regulations, standards and central control instances as autonomous systems are being gradually implemented. Organisational forms must be discussed, the need for national and international standardisation and regulation/cooperation, reflection on inspection by the authorities, where also the intermodal perspective is taken care of.The two cases defined in the dissemination work package (WP5) will have different level of vulnerability, where the first one is in a controlled environment (the airport) while the other is open (sailing in a fjord with unknown objects, traffic and users). **Deliverables:** 1. Methods for assessing effects of task assignments between vehicles and different organisations. 2. Report on intermodal experiences in an infrastructure setting, where vulnerabilities and threats (including exploration of cultural barriers) are analysed, this includes the technological autonomous infrastructure maturity which is analysed to identify possible threats	**SINTEF TS**
WP3: Technical, human and operational barriers to mitigate autonomous system risks (Based on WP1, WP2 giving input to WP4 and WP5) ***Objective***: To assure safety, security and resilience when operating autonomous systems in a structure of partly control through localized autonomy and central control centres. A theoretical platform will be established, supporting the assessment and development of barriers against hazards. Relevant theoretical contributions, research findings and methodical principles will be studied in order to define a set of concepts and methods to explore relationship between the technologies, Human Factors, and operational issues in control centres and localized in the autonomous systems. **Deliverables:** 1. Methods to be used to assess mitigating technical, human and regulatory measures 2. Methods/framework to be used to guide the building of operational centres, and verify and validate solutions 3. Report analysing MTO barriers to mitigate autonomous system risks	**MARINTEK**
WP4: Organisational and human factors, and regulatory measures for risk mitigation Based on WP1,2 and 3 ***Objective***: Develop measures for hazard mitigation in a remote control and monitoring centre, taking into account the role of the human factor. Measures include procedures and protocols, as well as regulatory measures with regards to responsibility clarification. Also the aspect regarding the organisational implementation of autonomous system will be covered, including the intermodal perspective. Collaboration between organisations and humans, cross disciplines and modes, is central elements. Reflection on cultural perspectives; e.g. the Scandinavian approach with strong collaboration between the workforces, management and the regulators. Different ways of organising work, and the challenges brought on by competitive forces, and reflection on specific autonomous mode regulations/standards and analysing them working in a total system. **Deliverables:** 1. Methods for assessment (verification and validation) of human factors in remote control and monitoring centers 2. Guidelines and processes for successful implementation of autonomous systems and intermodal perspective	**NTNU** **And SINTEF**
WP5a: Publication and dissemination (Reporting key issues from WP1 to WP5) ***Objective***: To disseminate the project results that enables the transition to a green, smart, safe and secure autonomous transport system. This will be done by case verification of the hypothesis, methods and results, publications in journals and scientific prints, participation in seminars and conferences. The project will create knowledge and a living document (a web site) containing lessons learned from the project. The web solution comprises a "living" repository of best practices and guidelines as well as social media features. This "living document" will be continuously updated and nurtured by a Community of Practise (CoP) for mutual learning and information sharing. The results and knowledge gained in this project will be communicated and disseminated among all the project partners in project activities, via the research network, HFC forum, and through the planned implementation processes among the project partners. The results will also be disseminated via seminars and education. The project aims at publishing 5-8 peer-reviewed papers. Relevant journals include Journal of Transportation Technologies, International Journal of Public Administration, Journal of Public Administration and Policy Research, Safety Science, Accident Analysis & Prevention. Scientific publication will be achieved through a series of articles in international peer-reviewed journals such as Journal of Cognition Technology & Work; Human Factors, The Journal of the Human Factors and Ergonomics Society, as well as several papers presented at international conferences. The project will also use case studies to verify the autonomy systems. The two cases selected will be one focused on the land side, the other with focus on the maritime side: **Deliverables:** *Papers and publications:* 1. Article on safety Hazards/Threats and challenges in autonomous systems, including the intermodal aspect. 2. Article on Risk based regulation of autonomous systems and overview of organisational structures 3. Journal Article describing the autonomous systems in a green perspective 4. Journal describing development of relevant methodology 5. Journal paper –with focus risk identification and risk levels 6. Journal paper –with focus Identify concrete risk, threats and vulnerability in autonomous systems	**SINTEF TS**

7. Journal paper – with focus Technical and operational barriers to mitigate autonomous system risks 8. Journal paper - with focus on Organisational and regulatory measures for hazard mitigation *Seminars and meeting, workshops:* 1. Opening seminar: ITS transport network 2. Midway seminar: First findings, open invitation and conference 3. Closing seminar 1: Actions towards the findings 4. Closing seminar 2: Findings and results from the PhD work 5. Workshops, Questionnaires and interviews with the participants signed a LOI; Authorities, Associations and Norwegian Industry (issues will be based on the content described in previous WP's) *Standardisation and regulation:* 1. Dissemination to standardisation and regulation work	
WP5 b: Verification and Validation **Objective**: Ensure that the results are verified and validated. The activities are: 1) Case verification land side; Autonomous snow-clearing of airports (Avoid/mitigate - Collision with aircraft and with people, Avoid the Destruction of object/infrastructure, Collision avoidance, Mitigate Hijacking) 2) Case verification sea side; Autonomous transport of goods by small vessels in fjords (How to identify collision of objects, Risk of security issues - Hijacking, Drift off/lose control). MARINTEK has already done some preliminary technical designs for the latter case. **Deliverables:** *Case verifications, including a check regarding the hypotheses within each field:* 1. Case verification on Hazards identification and risk levels 2. Case verification to Identify specific risk, threats and vulnerability in autonomous systems 3. Case verification on Technical and operational barriers to mitigate autonomous system hazards 4. Case verification Organisational and regulatory measures for hazard mitigation	**SINTEF TS**
WP6 a: Project management and steering committee **Objective**: Management of the project and contact with all involved personnel. **Deliverables:** 1. Involvement of reference group and foreign partners (meetings incl. financial costs) 2. Technical committee work 3. Daily management, workshops, seminars and dissemination of results	**SINTEF TS**
WP6 b: Financing of one PhD candidate at NTNU 1. PhD work and counselling (2017:1039; 2018:1075; 2019:1113)	**NTNU**

The total cost of the project is estimated to NOK 8.910 Mill. Cost for each work package is reported in the table above. The project includes a PhD scholarship.

4.Key perspectives and compliance with strategic documents

Compliance with strategic documents

The combination of technology and sociotechnical factors is a key part of MARINTEK and SINTEF TS. Both aim at maintaining a strong base of competence regarding the relationship between technology and society. Both research communities see this project as strategically important for the continuation of their core competency with a special focus on autonomous transport systems. The project may serve as a foundation of a future Centre for Research-based Innovation (SFI) within autonomous transport or similar.

Relevance and benefit to society

The project will generate new scientific knowledge and practical improvement measures related to how technology can be accepted and used. Knowledge from the project can be of great relevance for the Norwegian transport sector by making the industry better able to resolve key issues *before* entering the operations phase.

Environmental impact

Autonomy and fully or partly unmanned operation is one of the most promising candidates to obtain a safer and greener transport system. This project will contribute to release this positive environmental impact. The project is not expected to have any negative environmental consequences, it could support environmental issues related to improved documentation and knowledge related to environmental friendly results from the use of unmanned vehicles and automated transport systems.

Ethical perspectives

With regard to research ethics, we will follow established procedures regarding the storage of personal data. We will gather, store, analyse and publish our data in a way that will protect the interests and integrity of the individuals and organizations participating in the project. The project will be registered at the Norwegian Social Science Data Services (NSD).

Gender issues (Recruitment of women, gender balance and gender perspectives)

The Norwegian core project team consists of men and women. We encourage especially women to apply for the announced PhD, one women candidate has already showed interest in applying.

5. Dissemination and communication of results

Dissemination plan and communication are described in Work Package 5 “Publication and dissemination”.

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