Iquus Autonomy Best Practice

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About this guide

This starter guide is for individuals responsible for operating an iQuus system. It provides essential instructions for commissioning, operating, and maintaining the system. Please read this guide thoroughly before you begin.

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About iQuus

The iQuus system is designed to transform a modern agricultural machine into a (semi-)autonomous vehicle. The machine can still be operated manually by the user without any issues. When automation is desired, the user can activate the iQuus system to perform tasks autonomously.

The iQuus system operates by first recording a route using precise GPS points. Once recorded, this route can be replayed with various settings applied, such as hitch position, engine RPM, hydraulics, and PTO controls. Recording the route in advance allows for immediate verification that it is a logical and drivable path.

The iQuus system can control the following machine and implement functions:

- Hitch control
- Hydraulics (electronically controlled valves)
- Rear PTO
- Engine RPM
- Speed
- Seat switch
- External inputs and outputs

Please note that iQuus can only operate functions that the user can manually control. If a function is unavailable due to a tractor malfunction or incorrect tractor settings, iQuus will also be unable to operate it.

How iQuus works

The iQuus system operates as follows:

- The GNSS receiver calculates the tractor's exact position and sends it to iQuus.
- The tablet records and replays routes and controls the steering controller
- Pressing the road switch activates iQuus, allowing it to take control of the tractor.
- The tablet sends all command inputs to the Vehicle Drive Module (VDM).
- The VDM manages the machine controls, enabling iQuus to operate the tractor.
- The Automatic Brake Module slows the tractor during autonomous operation and enables emergency braking if needed.
- To return control to the driver, press the road switch for 3 seconds

Important Safety Information

This document describes an autonomous system, for which you are fully responsible and liable during use. Do not activate the system in areas where its use or a malfunction could cause physical injury, psychological harm, or other damage. Ensure that no people or animals are near the system when it is active. Use the system only on private property, and prevent it from accessing others' property, public spaces, or public roads. Take precautions to avoid any material, physical, psychological, or other damage in these areas.

In an emergency, prioritize your own safety. In an emergency, call 000. To restart the system after an emergency stop, please refer to Section 4.11, "Emergency Stop."

For further safety information, please refer to the supplied CE documentation

Risk Management

The operation of mobile machinery with autonomous functions can introduce hazardous situations not normally encountered on a farm site with conventional machinery.

The effective management of the risks associated with mobile machinery with autonomous functions requires input from diverse groups, ranging from researchers, design engineers, manufacturers, importers, distributors, owners, operators, project managers and safety and health representatives.

The risk management process should address the following questions.

- What are the potential scenarios for incidents? (see Appendix 6 for examples)
- What are their potential consequences in terms of safety and health?
- What controls are available and how effective are they?

Risk Register

It is important to identify risks and document them individually in a risk register. Each risk can be identified addressed in turn, and any additional risks can be identified and added to the risk register

Risk Matrix

A risk matrix is a valuable tool for controlling risks by visually mapping potential hazards based on their likelihood of occurrence and the severity of their consequences. By categorising risks into different levels, according to their likelihood and consequence, the farmer can prioritise their response efforts. This approach helps to allocate resources effectively, address the most critical risks first, and develop appropriate mitigation strategies. The use of a risk matrix ensures a systematic and structured method for managing risks on the farm and reduces the chance of overlooking significant threats.

Applying the Risk Matrix to Autonomous Vehicles on a Farm

When considering the deployment of the Iquus system on a farm, a variety of risks must be assessed. These risks can range from mechanical failures to collisions to environmental hazards. Using a Risk Matrix to evaluate these risks can help the farmer and other staff members prioritize safety measures.

The first step is to identify the key risks associated with the operation of AVs on the farm. Examples of risks include:

- System Malfunction: A vehicle's sensors, GPS, or software could fail, causing it to misinterpret its surroundings or lose control.
- Collisions with Humans or Animals: AVs may unintentionally collide with farm workers, livestock, or wildlife.
- Environmental Hazards: Weather conditions like heavy rain or flooding can induce wheel spin and may bog the tractor.

For each identified risk, assess the likelihood (probability) of the event occurring and the severity of its potential consequences. The likelihood can be classified on a scale from "Very Unlikely" to "Very Likely," while the severity can range from "Minor Impact" to "Catastrophic Impact." For example: Collisions with Humans: Likelihood = Extremely Rare, Severity = Catastrophic (in the event of injury or death)

Using the likelihood and severity assessments, plot each risk on the Risk Matrix. An example Risk Matrix can be seen below in Table 1. Risks in the "High Likelihood" and

"High Severity" quadrant should be prioritized for mitigation. For example, a system malfunction may fall into this category, requiring immediate attention through regular maintenance and robust software updates.

Monitor and Reassess

Risk management is an ongoing process. As technology and farm conditions evolve, the Risk Matrix should be regularly updated to reflect new insights and changing circumstances. Ongoing monitoring of the vehicle performance, as well as training for farm workers to interact safely with the vehicles, will help ensure that risks remain manageable

Table 1 - Risk Matrix

			Consequence					
			0 Little Consequence	1 Some consequence	2 Moderate Consequence	3 Serious Consequences	4 Very serious consequence	5 Catastrophic consequence
Likelihood	Almost Certain	5	5	6	7	8	9	10
	Likely	4	4	5	6	7	8	9
	Possible	3	3	4	5	6	7	8
	Unlikely	2	2	3	4	5	6	7
	Rare	1	1	2	3	4	5	6
	Extremely Rare	0	0	1	2	3	4	5

Untreated Risk Scores
8,9,10 (Extreme risk) - Task is not permitted. Risk controls are required to ensure residual risk is acceptable.
6,7 (High risk) - Task is not permitted. Risk controls are required to ensure residual risk is acceptable.
4,5 (Medium risk) - Task may proceed, however, risk must be reduced to 'as low as reasonably practicable' (ALARP).
1,2,3 (Low risk) - Task may proceed.

Table 2 - Example Risk Register

ID	Strategic Theme (e.g. operational, legal, financial, resource etc.)	The Risk What can happen and How it can happen	The Consequence	Existing Controls Description and Adequacy (only controls that are currently in place)	Risk Rating			Additional Risk Treatment Strategies	Risk Rating after controls		
					L (a)	C (b)	R (a+b)		L (a)	C (b)	R (a+b)
1	Operational	Collisions with Humans	Serious Injury or Death	Access Controls to site. Obstacle avoidance equipment. Emergency Stops.	0	5	5				
2	Operational	Engine overheating	Damage to engine	Engine temperature monitoring with remote emergency shutdown	0	4	4				
3	Environment	Too much chemical applied to land	Loss of crops, environmental damage	Existing chemical application controls,	2	1	3				

Employee Hazard Identification and Reporting

Effective reporting procedures are essential for maintaining a safe workplace and preventing accidents or injuries. Employees play a crucial role in identifying and reporting safety risks, as they are often the first to notice potential hazards in their environment. A clear, structured process for reporting these risks ensures that concerns are addressed promptly, reducing the likelihood of incidents and promoting a culture of safety within the organization.

The first step in any reporting procedure is ensuring that employees are aware of the channels available to them for reporting safety risks. It is important that these channels are easily accessible, well-publicized, and non-intimidating. Employees should feel comfortable reporting any safety issue, from minor hazards to more serious concerns, without fear of reprisal. This is where fostering a safety-first culture is key—employees need to understand that reporting risks is not only encouraged but required for the well-being of everyone on the team.

Once a safety risk has been identified, the reporting procedure should include clear steps for documenting and communicating the issue. A good reporting system allows employees to provide specific details about the hazard, including its location, the potential severity, and any immediate actions taken.

After a risk is reported, it is critical that the organization takes prompt and appropriate action. A designated safety officer or team should assess the reported risk, determine its potential impact, and decide on the necessary corrective measures. In many cases, this may involve investigating the situation further, conducting a risk assessment, and taking immediate steps to eliminate or control the hazard. Employees should be informed of the steps taken to address the issue and be kept updated on any further actions required.

It is important to be more deliberate in reporting and assessing risks on the farm when employing autonomous vehicles on farm. The reason is that risks that are not a problem for a manned vehicle may be a serious disruption to an autonomously operate vehicle. And for that reason, risks that could previously be safely ignored or addressed through informal mechanisms now may require deliberate addressing. An example of this is if a tree falls down in a paddock prior to a spraying operation. A vehicle operated by a employee familiar with the machinery and farm will be able to identify and steer around this disruption. An autonomously operated vehicle will come to a stop close to the obstruction and send a warning to the operator. If a new obstruction can be identified prior to starting an autonomous task, the route can be replanned to allow for the completion of the task without interruptions.

Mitigation

Once risks are prioritized, it is important develop identify existing controls in place and to develop further strategies to mitigate risks. For example:

- For **system malfunctions**, regular testing, redundancy protocols, and fail-safes should be implemented to reduce the likelihood of a failure.
- To address **environmental hazards**, AVs can be equipped with enhanced sensors capable of functioning in a variety of weather conditions, as well as anti-wheel slip detection systems and remote shutdown capabilities.
- For **collisions with humans or animals**, the Iquus system includes advanced obstacle detection and emergency stop capabilities, alongside this, clear farm signage indicating autonomous operation zones should be readily available and a variety of access controls in place.

It is important to note that mitigation measures are not just the installation of physical protections and technology solutions While physical safeguards, such as barriers, safety equipment, or automated systems, are vital components of any risk management strategy, they alone are often insufficient in addressing the full spectrum of risks in complex environments.

Effective mitigation involves a holistic approach that includes not only technical solutions but also organizational, procedural, and human factors that contribute to safety and risk reduction. One key aspect of mitigation is the development and enforcement of **safety protocols and procedures**. These guidelines define how risks should be managed, what actions to take in case of an emergency, and the steps required to minimize exposure to hazards. Regular training and drills are essential to ensure that employees understand these procedures and can act swiftly and appropriately when risks arise. Clear communication of safety standards and expectations is critical, as is fostering an organizational culture where safety is prioritized at all levels.

In addition to protocols, **human factors**—such as employee behavior, decision-making, and vigilance—play a significant role in risk management. While technology can help reduce human error, it cannot eliminate it entirely. Therefore, mitigation should include creating an environment that promotes safety awareness, encourages reporting of risks, and provides support for employees in identifying and addressing potential hazards. Empowering employees to recognize and report risks, and ensuring that they are trained in safe practices and behavior, can often be as effective as installing technological solutions.

Furthermore, **organizational culture** itself must be aligned with risk reduction efforts. This involves fostering an atmosphere where safety is seen as a shared responsibility, and where leadership demonstrates a commitment to safety through resources, training, and regular engagement with employees. Organizations that create open channels for communication, feedback, and continuous improvement in safety practices are more likely to prevent accidents and build long-term resilience against risks.

While physical barriers and technological solutions are essential components of risk mitigation, they must be part of a broader, integrated strategy that includes procedural safeguards, employee training, and an organizational culture that actively supports safety. Effective mitigation requires a comprehensive approach that addresses both the technical and human aspects of risk management to ensure a safer and more resilient environment.

Multiple Layers of Protection

The Swiss Cheese Model is a widely used approach for understanding and managing risks in complex systems, particularly in industries where safety is critical. The model illustrates how safety critical systems have multiple layers of protection, and that accidents or failures occur due to weaknesses in multiple layers of protections lining up. These weaknesses, much like the holes in a slice of Swiss cheese, can align in such a way that a risk or hazard is able to pass through the system and lead to a failure or accident.

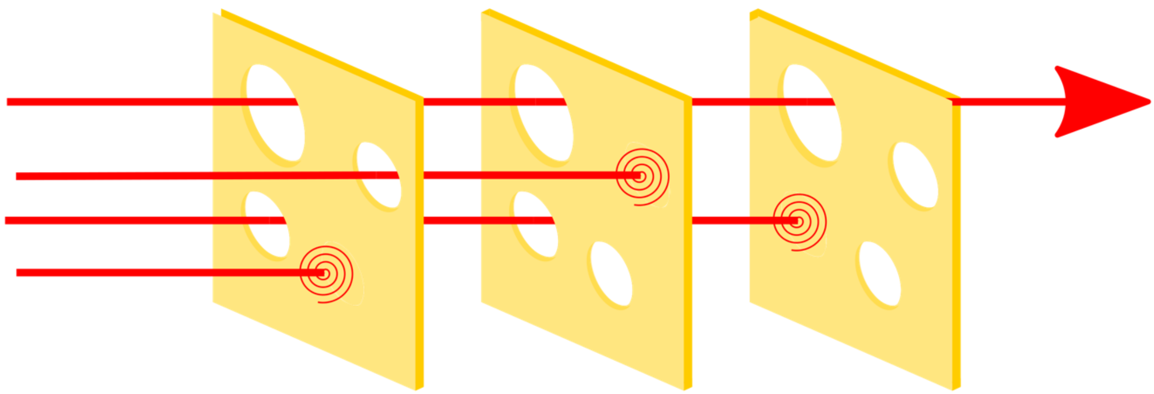


Figure 1: The Swiss Cheese Model, showing how failures happen if multiple weaknesses line up in multiple layers of protection

Each layer of defence in a system is designed to mitigate risks. These layers can include physical barriers, procedures, automation, or human oversight. Each layer of defence has inherent weaknesses, such as errors, system failures, or human mistakes. These weaknesses are represented by holes in the cheese. An accident or failure occurs when the holes in different layers line up, creating a clear path for a hazard to pass through and cause harm.

The Swiss Cheese Model highlights the importance of creating robust and redundant systems of defence. To reduce the likelihood of accidents, organizations must strive to:

- Identify and address weaknesses in each layer of defence.
- Ensure that layers of defence are not overly dependent on a single point of failure (e.g., reducing reliance on human error or outdated technology).
- Use proactive safety measures, such as regular audits, training, and process improvements, to "close" or minimize the holes in each defence layer.
- Learn from past incidents and adjust defences accordingly to prevent future alignment of holes.

For example the risk of crashing an autonomously operated vehicle into a structure has multiple safeguards in place.

- Correct mapping of routes through the farm,
- Max line deviation error will trigger stop if tractor goes off route,
- Obstacle avoidance radars detects steel structures very reliably,
- Human-in-the-loop capability to trigger emergency stop remotely,
- Farm fences function as physical barriers,
- Positive communications with staff allows multiple people to monitor platform remotely and trigger safety stops if necessary.

Only some of these measures requires a human-in-the-loop in order to maintain effectiveness, this allows for safety measures to be in place if the human-in-the-loop mechanism fails due to lapse in attention etc.

Designing a Farm System for Autonomous Operations

The following fundamental principles need to be built into farm design and planning processes early in the project:

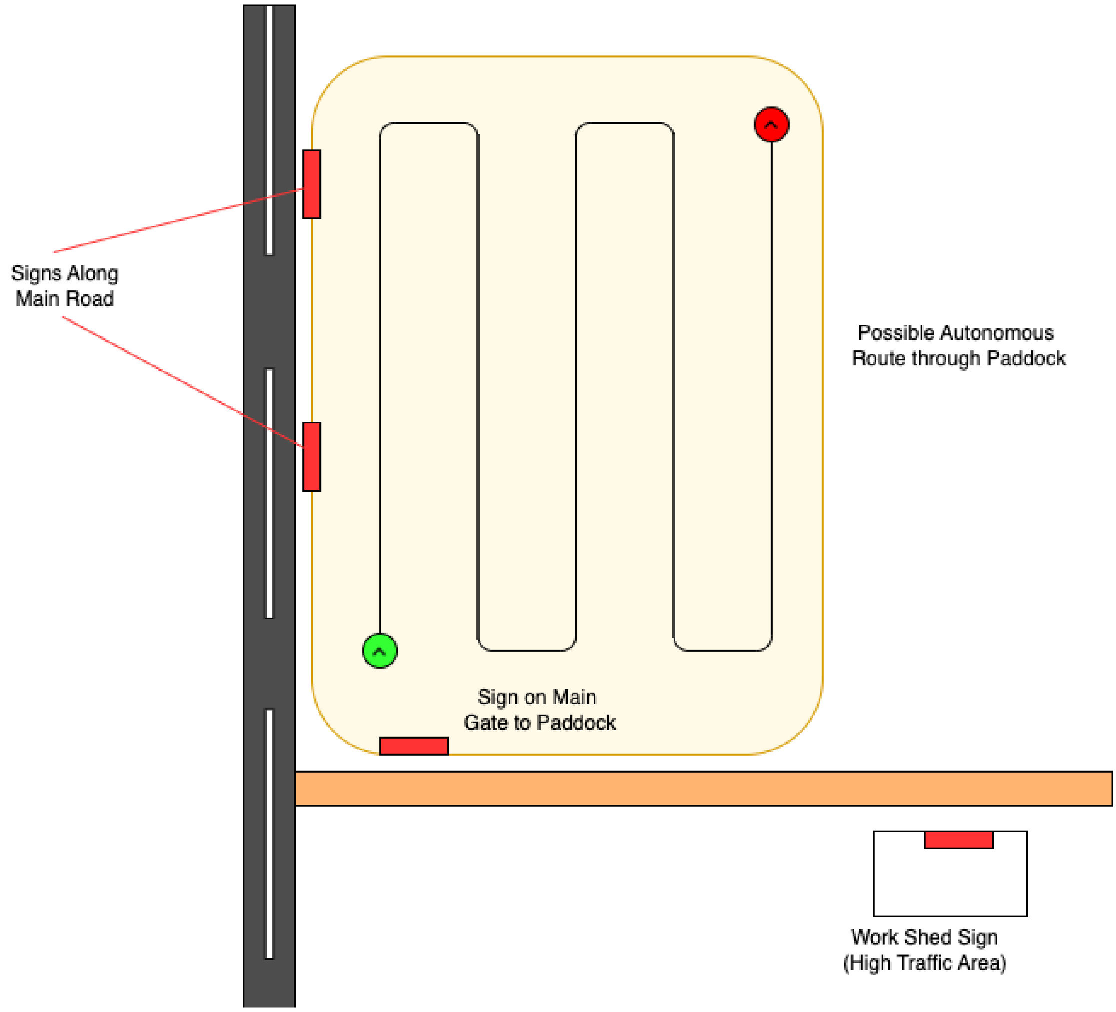
- risk management (See chapter 1)
- designing and planning for mobile machinery with autonomous functions
- managing and minimising interactions
- infrastructure to support mobile machinery with autonomous functions.

Designs and plans for farms should take into account the limitations of any autonomous farming technology being used, including:

- application of engineering and system controls to safety processes and practices
- modification of established planning and operational processes
- verification of system data (e.g. surveys) to validate farm designs and plans
- knowledge and competency of planning and operational personnel.

Engineering and System Controls

Use of signage



Positive Communications

Scheduling and Notifications

WARNING

AUTONOMOUS AGRICULTURAL OPERATIONS

Appendix 1 - Risk Register

Risk No/ ID	Strategic Theme (e.g. operational, legal, financial, resource etc.)	The Risk What can happen and How it can happen	The Consequence	Existing Controls Description and Adequacy (only controls that are currently in place)	Risk Rating			Additional Risk Treatment Strategies (to be implemented to reduce the risk rating to an acceptable level)	Risk Rating after controls		
					L (a)	C (b)	R (a+b)		L (a)	C (b)	R (a+b)

Hazard Control

Hazards to Autonomous Equipment

It is crucial to identify potential hazards before operating autonomous equipment. These hazards can be categorized as follows:

1. **Static Hazards**: Fixed objects such as trees and structures.
2. **Movable Hazards**: Objects that can be moved, like parked vehicles or piles of soil, gravel, or compost in the operating area.
3. **Dynamic or Unpredictable Obstacles**: Moving objects like animals (e.g., kangaroos) or people walking through the field of operation.
4. **Obstructions to Normal Operation**: Features such as gullies, trenches, or areas eroded by heavy rainfall.

Once hazards are identified, it is essential to assess the risks they pose to autonomous equipment. Additionally, the suitability of the equipment for the task within the operating area should be evaluated.

Hazards posed by machinery

It is important to identify the hazards that autonomously operating machinery may pose to other systems and infrastructure within the farm. This includes potential impacts on farm infrastructure such as fences and structures, as well as implications for safe operation across the entire farm. For instance, autonomous machinery in one part of the farm might restrict access to other areas, potentially complicating operations that require access to those areas.

To maximize safety, it is crucial to consider how autonomous operation can be scheduled around other farm activities. This may involve planning routes, setting operational boundaries, and coordinating with other machinery and personnel to avoid conflicts. By understanding the spatial and operational limitations of autonomous equipment, farms can better manage risk and ensure efficient and safe use across the entire property.

Hazard Controls

To reduce the risks associated with certain hazards, it is essential to implement additional risk management controls alongside the safety features provided by the autonomous system. These controls can include:

1. **Physical Barriers or Signage**: Installing fences, barriers, or clear signage to guide both the autonomous equipment and any human workers or animals on the farm.
2. **Safety Zones**: Defining no-go zones or safety zones where autonomous machinery is restricted from operating, particularly in high-traffic areas or near critical infrastructure.
3. **Scheduled Operation Times**: Coordinating the operation of autonomous machinery with other farm activities to minimize conflicts and ensure that equipment has access to all areas when needed.
4. **Emergency Stop Systems**: Implementing manual or remote emergency stop systems that allow human operators to halt autonomous equipment in case of an emergency or unforeseen obstacle.
5. **Regular Maintenance and Inspections**: Conducting regular checks on both the autonomous machinery and any supporting infrastructure to ensure they are in good working condition and to prevent malfunctions.
6. **Training and Awareness**: Educating workers and other personnel about the capabilities and limitations of the autonomous system to ensure they can operate safely around the equipment.
7. **Real-Time Monitoring**: Using monitoring systems to track the movements and performance of autonomous machinery in real time, allowing operators to intervene if necessary.

By implementing these additional risk management measures, the overall safety of autonomous operations on the farm can be significantly enhanced, reducing the likelihood of accidents and improving operational efficiency.

Risk management for operating the IQuus system.

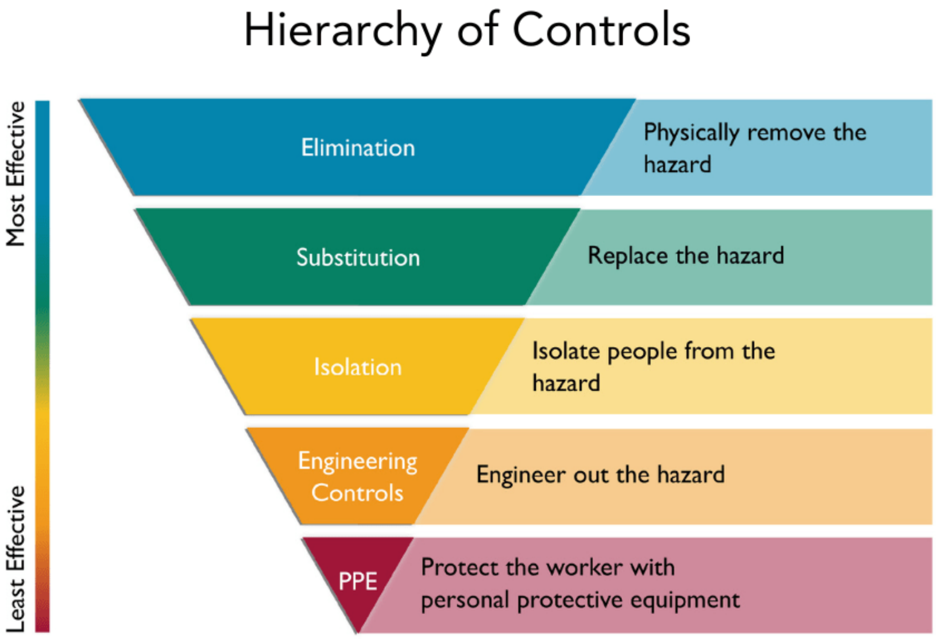
A risk management approach is crucial when designing operations around autonomous machinery to ensure safety and minimize potential hazards. Below is an example of a Risk Register for autonomous operation:

RISK ANALYSIS

CONSEQUENCE →

LIKELIHOOD ↓

	1. INSIGNIFICANT Dealt with by in house first aid	2. MINOR Treated by medical professionals, hospital out patients	3. MODERATE Significant non permanent injury overnight hospital stay	4. MAJOR Extensive permanent injury eg. Loss of fingers, extended hospital stay	5. CATASTROPHIC Death, permanent disabling injury eg. Loss of hand, quadriplegia
A. Almost certain to occur in most circumstances	MEDIUM 8	HIGH 16	HIGH 18	CRITICAL 23	CRITICAL 25
B. Likely to occur frequently	MEDIUM 7	MEDIUM 10	HIGH 17	HIGH 20	CRITICAL 24
C. Possibly and likely to occur at sometime	LOW 3	MEDIUM 9	MEDIUM 12	HIGH 19	HIGH 22
D. Unlikely to occur but could happen	LOW 2	LOW 5	MEDIUM 11	MEDIUM 14	HIGH 21
E. May occur but only in rare circumstances	LOW 1	LOW 4	LOW 6	MEDIUM 13	MEDIUM 15

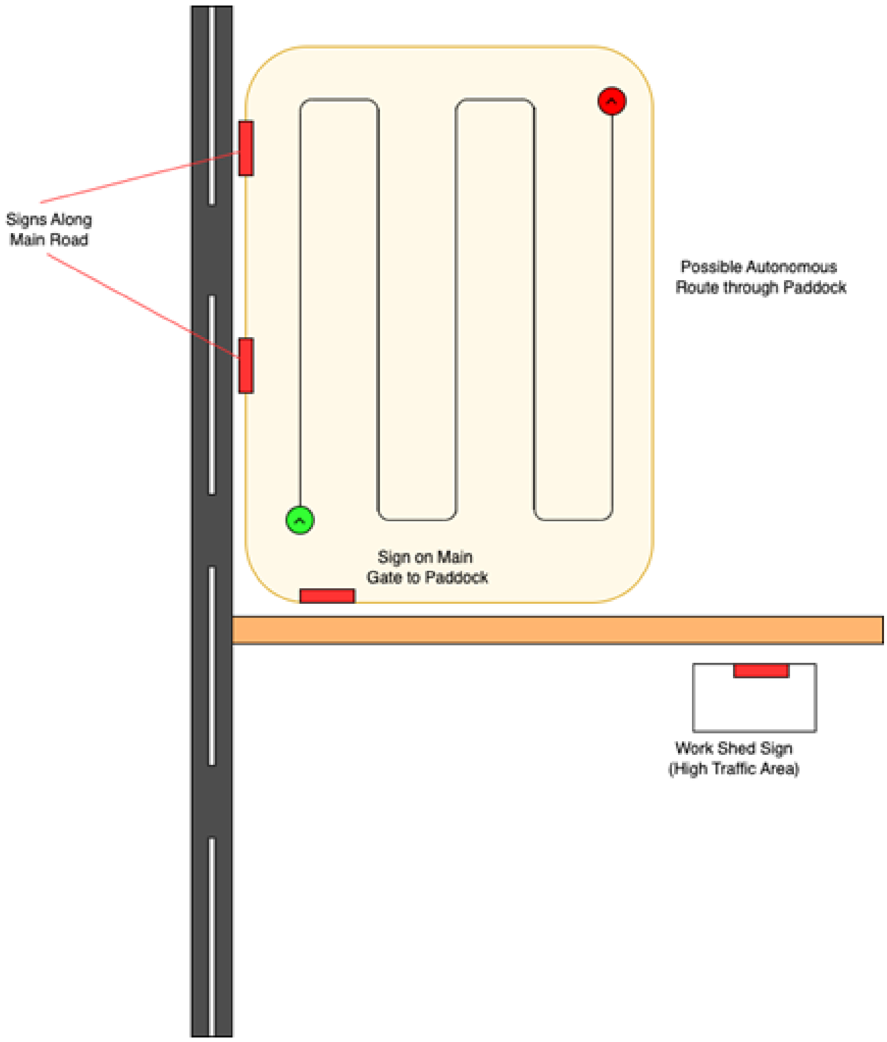


When mitigating risks, it is important to follow the hierarchy of control, which prioritizes safety measures based on their effectiveness in reducing or eliminating the risk.

Site Specific Risk Assessment

It is essential to assess risks for a specific operation based on the unique conditions of the site. Factors that may influence risk on certain sites include:

1. **Site-Specific Infrastructure**: The presence of structures, roads, fences, or other fixed elements that could pose risks to machinery or personnel.
2. **Water Content and Soil Characteristics**: High water content or specific soil types may increase the risk of sliding or wheel slip, particularly in wet or uneven terrain.



3. **Obstructions to Communication Signals**: Physical barriers or environmental factors that may interfere with communication signals, affecting the operation of autonomous systems.
4. **Access Requirements**: The need for clear and unimpeded access to different areas of the site, which may be hindered by obstacles or operational scheduling.

Considering these site-specific conditions helps ensure a more accurate risk assessment and the implementation of effective safety measures tailored to the environment.

When planning an autonomous route through a paddock, it is important to consider the following:

1. **Access Requirements**:
    - Ensure the route allows easy access to the area of operation and neighbouring areas.
    - Avoid blocking gates, pathways, or other critical entry points needed by people or machinery.
2. **High-Traffic Areas**:
    - Plan routes that steer clear of areas with frequent vehicle or personnel movement.
    - Use barriers or designated paths to separate autonomous machinery from high-traffic zones.
3. **Un-Trained Personnel**:
    - Avoid areas where untrained or unauthorized people might be present.
    - Clearly mark autonomous operation zones with signs or barriers to prevent unintended access.
4. **Parallel Work Operations**:
    - Check for any ongoing work nearby that might overlap with autonomous operations.
    - If possible, delay or reschedule nearby activities to avoid interaction with the autonomous machinery.
    - Coordinate with other teams to ensure clear communication and safety measures are in place.

By carefully addressing these factors, autonomous operations can run safely and efficiently, minimizing risks and avoiding disruptions.