1 Evaluation

1.1 Evaluation Interviews

The interface and ontology were evaluated through four interviews with two operators and two drivers. Three interviewees were the same individuals who participated in the data collection phase described in the interview section. The fourth interviewee, designated as Operator 2, had several years of experience as both a slag truck driver and operator, providing extensive and unique insights into both professions.

Each interview lasted between 2 to 4 hours and was both recorded and transcribed. The evaluation interviews consisted of two parts:

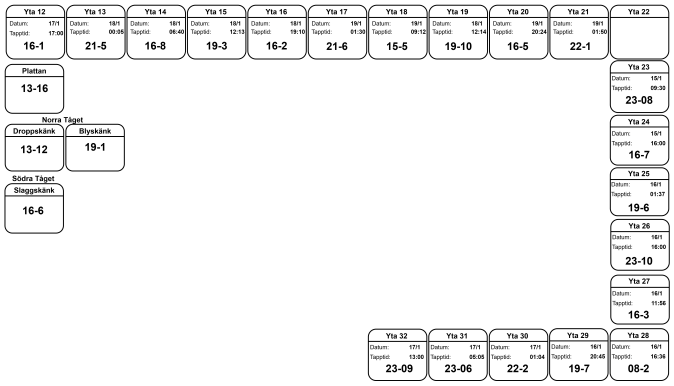
1.1.1 Part 1: Scenario-Based Evaluation

1. Five occupation-specific questions for operators and six for drivers
2. Seven different scenarios are presented on an overview map of the solidification sites
    - Interviewees were asked to describe their actions in each scenario
    - Then, they were informed about the interface/ontology's reaction to the identical situation
    - Finally, they assessed the correctness of the system's behavior

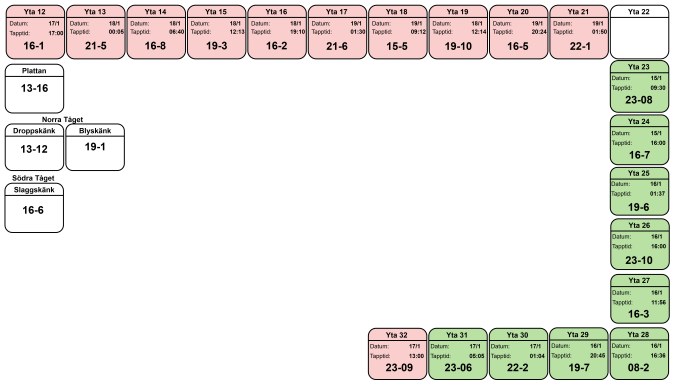
The purpose of the scenarios was to compare the ontology's reasoning capabilities with those of the operators and drivers. Acceptable reasoning was defined as a system exhibiting the same behavior as the participants, provided that their reasoning was sound. Superior reasoning was defined as the system's ability to detect risks that the current system may have overlooked.

Scenarios

The default scenario, which was the base for the evaluation, is taken straight from an actual real case. In Figure 1, this scenario can be seen with date, start time for solidification and ladle number; Figure 1b is the same scenario but with coloring so the reader can easily see which ladles are not solidified (red) and which are (green).



(a) Default Scenario

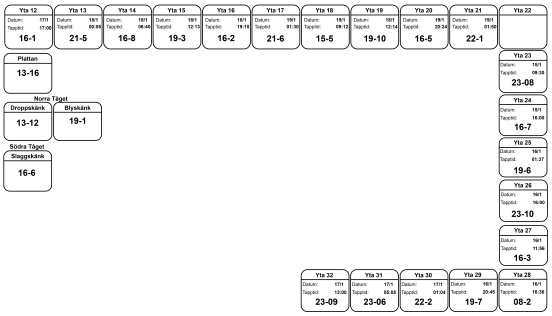


(b) Same scenario with coloring

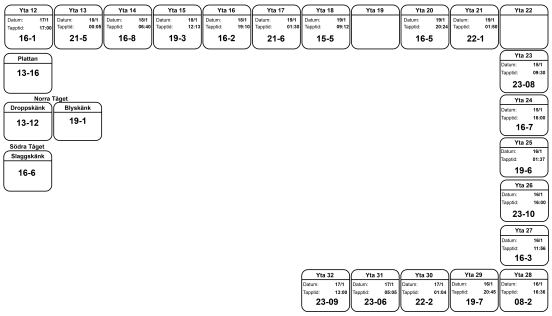
Figure 1: Default Scenario

Figure 2 shows the seven scenarios to which all interviewees were asked to respond. The difference

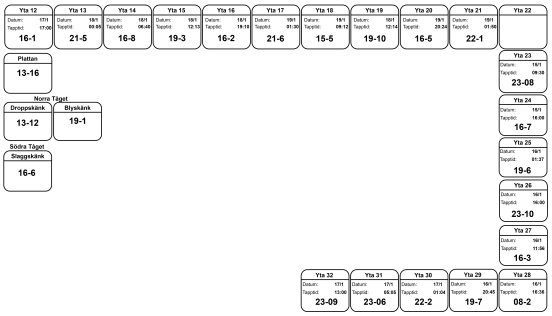
between the interviews with operators and drivers is that the drivers' scenarios did not include any date or time for solidification because a driver does not have access to this information (only available on the whiteboard). To simulate reality, drivers could only see the ladle number.



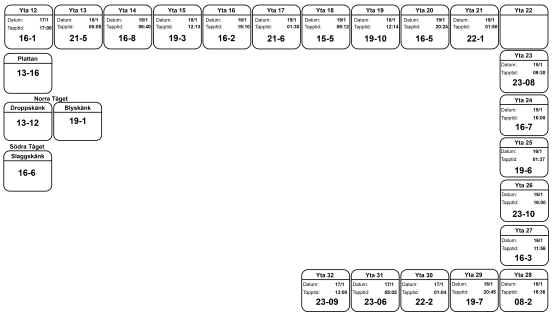
(a) Scenario 1



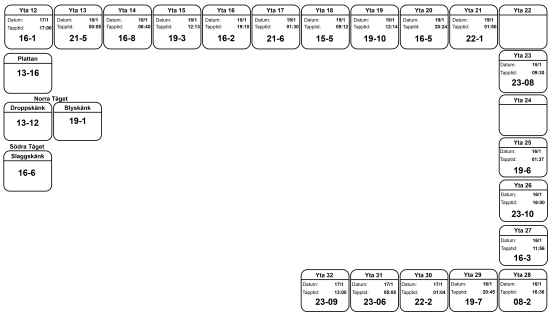
(b) Scenario 2



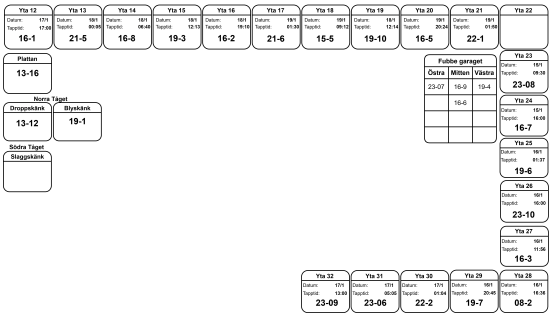
(c) Scenario 3



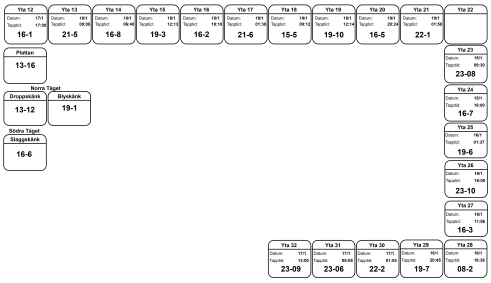
(d) Scenario 4



(e) Scenario 5



(f) Scenario 6



(g) Scenario 7

Figure 2: Ladle management scenarios

Explanation for Scenario 1 to 7:

1. **2a:** The question here is where would you place ladle 16-6, and which ladle would be next to be emptied and then driven to the south train? In this scenario, the correct answer is to place the slag ladle 16-6 on area 22 (Yta 22 in Swedish). This is because the previous area (21) is occupied with a newly poured slag ladle (not solidified), and the next area (23) with ladle 23-08 has solidified for 120 hours, which is safe to empty and then used in production.

2. **2b:** Same question here, where would you place 16-6, and which would be the next ladle for the south train? This scenario is quite common and could potentially lead to an accident. In Figure 1b, we can see that the ladles before area 22 are red, meaning they are not solidified. So if a

participant's answer is to place 16-6 on area 19, then the next ladle to be emptied and used in production (emptied and placed on the south train) could cause an explosion when the driver empties the ladle where the slag has yet to be solidified, so the correct answer to this question is to place 16-6 on area 22 and then use 23-08 from area 23 in production.

3. **2c:** In this situation, the following ladle to be used (23-08) is filled with either liquid or slag shell or both. This has the potential to result in a severe accident. Is there any way for the interviewee to know this? If not, could this result in the ladle being placed on the south train? If the interviewee is aware of this, they should determine the appropriate placement for 16-6 and identify the upcoming ladle to be used for production. The solution is 16-6 to area 22, skip 23-08 on area 23, and then use 16-7 from area 24.
4. **2d:** Ladle 23-08 has some maintenance that needs to be performed. It is essential not to use maintenance ladles during production when this could be a risk in itself. Is there any way for the respondent to know that 23-08 has maintenance? If not, could this ladle be used in production? Lastly, if the participant knows this information, where should ladle 16-6 be placed, and which is the next ladle to use for production? The solution remains unchanged from the prior situation: 16-6 to area 22, ignore the next area, and use 16-7 from area 24.
5. **2f:** This question regards the Furberg (also called Fubbe) garage, where empty and ready-for-production ladles can be found. We need to use a ladle from Furberg Garage, but how do you determine which one is available and which one to use? Do you need to notify the driver or operator? There is no correct answer here; the question is more focused on communication between drivers and operators and whether the whiteboard is in accordance with reality.
6. **2g:** You can only empty ladles between 6.30 am and 6.30 pm. For the night shift, drivers must empty ladles in advance. This question proposes that ladle 23-08 could not be emptied (which happens frequently), but 16-7 and 19-6 are empty. Here, the question is if there is any way for the operator or driver to know this, and if they do, where should 16-6 go, and which would be the next ladle for production? The answer is 16-6 to area 22 and 16-7 to the south train.

1.1.2 Part 2: System Demonstration and Detailed Evaluation

After Part 1, interviewees received a demonstration of the interface, during which the various components were explained, and participants were allowed to interact with the system. Then, 23 questions were posed:

- 14 questions were answered using a quantitative Likert scale (1-5) and a qualitative explanation:
  - 1 indicated strong disagreement
  - 5 indicated strong agreement
  - Respondents provided explanations/justifications for their quantitative assessments
- 9 questions were purely qualitative, where numerical scoring was not applicable

For example, when questioned about the interface's intuitiveness, a rating of 1 would signify a strong disagreement that the interface is intuitive, while a rating of 5 would suggest a firm agreement. The qualitative component allowed respondents to provide further details and explain their numerical assessments. Other questions, such as "Are there any parts of the interface that are confusing or difficult to navigate?", were purely qualitative and did not use the Likert scale.

This methodology aimed to comprehensively evaluate the interface and ontology, combining quantitative assessments with valuable qualitative insights from experienced professionals in the field.

1.2 Evaluation Results

The findings are grouped below by the two occupations (operators and drivers).

1.2.1 Results from Part 1: Operators

This section provides the findings from the scenario-based evaluation for Operator 1 and Operator 2.

Occupation-Specific Questions

Table 1 summarizes the responses from Operator 1 and Operator 2 to the five occupation-specific questions.

Table 1: Operator Responses to Occupation-Specific Questions

Question	Operator 1	Operator 2
1. How often do you double-check that the ladle on the south train matches the board?	Almost every time, it has become a routine to check.	Every time.
2. How do you know which ladles are undergoing maintenance?	Through the Maximo program and/or the whiteboard.	We don't know unless someone wrote it on the board half a month ago. Total chaos.
3. Do you always know where the ladles are located?	For freezing ladles, there are limited locations. There's no routine for other ladles, and one always needs to double-check.	In theory, we know, but in practice, it's different. We usually see approximately where the ladle is, but it's unclear. It's half the truth.
4. How often must you communicate board information to slag truck drivers?	Mostly for deviating ladles, about two ladles per week. Routine communication is frequent.	Every time we write a fleet skill, I think only our shift does that. Often, we tell them (via phone) which ladle to take and where to put the other, probably 80% of the time.
5. How often must you double-check that reality matches the board?	At least once per shift rotation, especially after a free shift. Considering all shift teams, probably three times per week.	Every morning shift rotation, and it can be wrong on Monday, Tuesday, Wednesday, and Thursday. So it's guaranteed to be wrong at least twice in four days during a morning week.

Scenario-Based Evaluation

Table 2 presents a summary of the responses from Operator 1 and Operator 2 for each of the seven scenarios, along with their evaluation of the system's response.

Table 2: Scenario-Based Evaluation Results

Scenario	Operator 1 Response	Operator 2 Response	System Response	Operator 1 Evaluation	Operator 2 Evaluation
1	16-6 to area 22, 23-08 to south train	16-6 to area 22, 23-08 to south train	16-6 to area 22, 23-08 to south train	OK	OK
2	Initially: 16-6 to area 19, 16-5 to south train. After discussing and more time to think, it was later corrected to: 16-6 to area 22, 23-08 to south train	16-6 to area 22, 23-08 to south train	16-6 to area 22, 23-08 to south train	OK	OK
3	If known: 16-6 to area 22, 16-7 to south train.	If known: 16-6 to area 22, 16-7 to south train	16-6 to area 22, 16-7 to south train	OK	OK

Continued on next page

Table 2 – continued from previous page

Scenario	Operator 1 Response	Operator 2 Response	System Response	Operator 1 Evaluation	Operator 2 Evaluation
4	If known: 16-6 to area 22, 16-7 to south train, but says that "this is very hard to keep track of"	If known: 16-6 to area 22, 16-7 to south train, but says there is no way of knowing this and says "it would be guaranteed that the ladle would go into production"	16-6 to area 22, 16-7 to south train	OK	OK
5	16-6 to area 22, but area 24 would be safer if time for area 23 is unknown, then 23-08 to south	16-6 to area 24, 23-08 to south train, also says that this exact scenario has happened multiple times and that this was prevented by calling the driver	16-6 to area 24, 23-08 to south train	OK	OK
6	Slag truck driver would inform via phone, the operator would update the whiteboard manually	Often, the board doesn't match reality in the Fubbe garage, but they usually inform via phone which ladle they drive to the south train	If the user moves 23-07 to south train, it's immediately visible	OK	OK
7	16-6 to area 22, 16-7 to south train	16-6 to area 22, 16-7 to south train	16-6 to area 22, then skip 23-08 and take 16-7 to south train	OK	OK

Key Findings from Operators Part 1

1. Both operators consistently double-check ladle information, indicating a lack of trust in the current system.
2. There's a significant discrepancy in how operators access maintenance information, suggesting inconsistent practices across shifts.
3. Ladle location tracking is challenging and often requires verification.
4. Communication with slag truck drivers is frequent to make sure that the whiteboard aligns with the reality of the ladle's status and placement.
5. The need to verify board information is high, with discrepancies occurring multiple times per week.
6. In all scenarios, the operators' evaluated the system's proposed actions as correct, suggesting that the new system's logic matches experienced operators' decision-making.
7. Scenario 2 revealed a potential safety issue where an operator's initial response could have led to an accident, which the system would have prevented.
8. Scenario 4 highlighted that tracking which ladles need maintenance is almost impossible. The current system greatly increases the likelihood of introducing these ladles into production, potentially causing accidents.
9. Both operators positively evaluated the system's responses to the scenarios, indicating that the new system could improve safety and efficiency.

These findings suggest that the new system could address many current challenges operators face, particularly regarding information accuracy, communication, and safety. The new system's capability for drivers to update the actual location of the ladles in real-time is especially promising.

The alignment between the system's responses and the operators' decisions in most scenarios indicates that the system's logic is sound and reflects best practices. In one case, it could have foreseen a potential accident.

1.2.2 Results from Part 1: Slag Truck Drivers

This section presents the results from the scenario-based evaluation for Slag Truck Driver 1 and Slag Truck Driver 2. These individuals are the same interviewees from the knowledge modeling in section. First, the responses to six occupation-specific questions are presented, followed by the results from the seven scenarios.

Occupation-Specific Questions

Table 3 summarizes the responses from Slag Truck Driver 1 and Slag Truck Driver 2 to the five occupation-specific questions.

Table 3: Slag Truck Driver Responses to Occupation-Specific Questions

Question	**Driver 1**	**Driver 2**
1. How often do you double-check which slag ladle should be taken into production next?	Max once per shift.	You often call and say, "I'm going to take the slag from the south train now. Which area should it go to?" For example, area 22. Then you've double-checked. If you arrive and are unsure, you at least have something to go on.
2. If there is more than one gap among the solidification areas, how often do you estimate that you call to double-check which slag ladle should be taken into production next?	I'd rather call than guess.	In such a case, I always double-check. I would estimate there's more than one gap once every workweek.
3. How often would you estimate that Blykaldo doesn't get the ladle they "expect"? Do you always call and inform them about this?	Yes, I always call. It doesn't happen often.	It often happens that operators don't get the ladle they expect; I would estimate once or twice per work week. And I always call and inform them about this if I think they're not getting the ladle they expect.
4. A lead ladle should be placed onto the platform and then poured into Blyraffen (further lead processing) after a certain number of hours (depending on how hot the lead was when poured). How do you know what temperature the lead had and, thus, when you can pour the lead?	The operators have to tell me when I should pour the lead.	I must have a dialogue over the phone with Blykaldo about the temperature at tapping and when the lead was tapped. Then I have to keep track of this myself, meaning after how many hours (depending on the temperature) I can pour the lead into the refinery. Then, I also have to call the refinery when it's time to deliver the lead to check if they have the possibility.

Continued on next page

Table 3 – continued from previous page

Question	Driver 1	Driver 2
5. Would it help you, as a slag truck driver, to know the level and how long a ladle has been solidifying when it comes to emptying a slag ladle?	It doesn't matter to me for lead solidification.	It doesn't matter to us.
6. Have you experienced the emptying of a ladle that is not solidified?	Never happened to me, but it has happened to colleagues, at least once in the last 12 months.	Once or twice in the last year.

Scenario-Based Evaluation

Table 4 presents a summary of the responses from Slag Truck Driver 1 and Slag Truck Driver 2 for each of the seven scenarios, along with their evaluation of the system's response.

Table 4: Scenario-Based Evaluation Results for Slag Truck Drivers

Scenario	Driver 1 Response	Driver 2 Response	System Response	Driver 1 Evaluation	Driver 2 Evaluation
1	16-6 to area 22, 23-08 to south train	16-6 to area 22 and 23-08 to south train	16-6 to area 22, 23-08 to south train	OK	OK
2	16-6 to area 22, 23-08 to south train	Would first call. Then 16-6 to area 22 and 23-08 to south train	16-6 to area 22, 23-08 to south train	OK	OK
3	If known: 16-6 to area 22, 16-7 to south train. There's no way to know if a ladle contains a slag shell or liquid unless you check each time, which no one does.	There's no way to know this unless you always look down into the ladles beforehand. If known: 16-6 to area 22 and 16-7 to south train.	16-6 to area 22, 16-7 to south train	OK	OK
4	If known: 16-6 to area 22, skip 23-08, and take 16-7 to the south train. There's no way to know if a ladle is currently under maintenance.	Only if it's marked, which they aren't always, otherwise it will be taken into production. If known: 16-6 to area 22 and 16-7 to south train.	16-6 to area 22, 16-7 to south train	OK	OK
5	16-6 to area 22, would call to double-check	Would call and double-check. But I would put 16-6 on area 24 and then take 19-6.	16-6 to area 24, 19-6 to south train	OK	OK
6	Would call to ask which ladles are available	Go there and check or call the operators who can say which ladle they want.	If the user moves 23-07 to the south train, it's immediately visible	OK	OK
7	16-6 to area 22, 23-08 to south train	16-7 to area 22 and 23-08 to south train.	16-6 to area 22, then skip 23-08 and take 16-7 to the south train	OK	OK

Key Findings from Slag Truck Drivers Part 1

1. Both drivers consistently double-check information, especially when there are gaps in the solidification areas, indicating a cautious approach to safety.
2. There's a high reliance on communication with operators for critical information, such as solidification time, ladle placement, and lead pouring times.
3. The drivers' responses aligned with the system's proposed actions in all scenarios, indicating that the new system's logic matches experienced drivers' decision-making.
4. Maintenance status in scenario 4 and risks in scenario 3, are mostly unknown to the drivers; the system could provide additional safety measures here.
5. Both drivers positively evaluated the system's responses to the scenarios, suggesting the new system would improve safety and efficiency.
6. The current system lacks a reliable way to track ladle maintenance and material status in the ladle, which the new system could address.
7. In scenario 5, a discrepancy was observed where Driver 1 positioned the newly poured slag ladle in the leftmost area. In contrast, both Driver 2 and the interface placed it in the theoretically safest area, which is consistently the rightmost position. In the scenario the slag ladle could not be emptied but was solidified for a valid time, thereby eliminating any immediate risk associated with its emptying. However, this scenario highlights the absence of a precise routine for handling such cases. Notably, Driver 1 later agreed with the system's placement and acknowledged it as the safest option.
8. A very noteworthy discovery emerged from the evaluation of scenario 3 (found in Figure 2c), specifically when discussing empty ladles potentially containing slag shells or liquid - a severe safety hazard. Driver 1 candidly admitted that the only way to detect this risk is by physically inspecting each ladle, a practice they noted is rarely performed, stating "There's no way to know if a ladle contains a slag shell or liquid, unless you check each time which no one does." While Driver 2 stated always to conduct these inspections, the discrepancy between these responses highlights a critical vulnerability in the current system. This inconsistency in safety practices poses a substantial risk to operators during the slag pouring process, potentially leading to dangerous explosions.

These findings indicate that the new system could address many challenges slag truck drivers face, particularly regarding information accessibility, communication with operators, and safety enhancements.

1.2.3 Results from Part 2: Operators

This section presents the results from the evaluation interviews conducted with two operators. The results are organized based on the key aspects of the system that were evaluated.

User Interface and Functionality

Both operators found the interface intuitive and easy to use. Operator 1 rated the interface's intuitiveness as 4 out of 5, suggesting potential for improvement with increased familiarity. Operator 2 also rated it 4, emphasizing the system's significant assistance in preventing mistakes in ladle handling.

Regarding ease of finding and understanding information, Operator 1 gave a perfect score of 5, while Operator 2 rated it 4, anticipating improvement to 5 with increased familiarity. Both operators appreciated the color coding and layout. Operator 2 noted, "Now anyone can see where they [the ladles] should go." Operator 1 stated, "It's good that the areas are either green or red, OK or not OK." while Operator 2 appreciated the clear visualization of slag levels and being able to see the contents of the ladle.

The functionality of the system received high marks from both operators:

- Operator 1 rated the system's support for necessary ladle handling functions as 5/5, deeming it "absolutely" sufficient for solidification operations.
- Operator 2 also gave a 5/5 rating, emphasizing that the new system is "5000% better than what we have now."

Efficiency Improvements

Both operators agreed that the new system would significantly improve efficiency and safety:

- Operator 1 rated the system's ability to improve task efficiency as 4/5, noting its particular benefit for slag truck drivers.

- Operator 2 provided a rating of 4 out of 5, estimating a time reduction of approximately 10 hours during their morning shift rotation. Additionally, Operator 2 observed that the potential time savings for supervisors could be even more substantial. They stated, "It is a half-time position to keep track of ladles/ladle handling", indicating that some supervisors dedicate approximately 20 hours per week to this task.
- Operator 2 highlighted improved planning capabilities: "Now they [slag truck drivers] will be able to plan their day completely on their own without having to call and ask us for all the information."

Safety Improvements

- Operator 1 rated the system's safety improvement as 4/5, noting the most significant increase would be for slag truck drivers. They cautioned that excessive automation might lead to over-reliance on the system, emphasizing the continued importance of human oversight.
- Operator 2 gave a perfect 5/5 rating, stating, "If you make a mistake with this system, you must make a manual mistake. This is perfect; you can see directly where to place and retrieve the ladles."

Risk Prevention

Both operators identified several risks that the new system could prevent:

- Miscommunication between operators and slag truck drivers
- Accidents due to incorrect ladle selection or placement
- Issues with maintenance scheduling and tracking
- Problems with overflow ladles or ladles with slag shells

Operator 2 emphasized the system's accident prevention capabilities: "From an accident perspective, there can't be accidents with this system", they further elaborated, "You will not empty a slag ladle that is marked red."

Operator 1 highlighted the importance of documentation in the new system: "With documentation, information won't fall between the cracks; there are many risks that can be eliminated with the new system." They also noted the system's ability to prevent risks related to slag truck drivers taking the wrong ladle, which is information only available to them via telephone at present.

Communication Improvements

Both operators noted significant improvements in communication:

- Operator 1 emphasized the importance of shared information: "That both parties have the same information, the same view of reality."
- Operator 2 pointed out how the system reduces human error: "You will eliminate the risk of me as an operator making a mistake, if I with the current system accidentally say to the driver, to empty a slag ladle which has not been solidified, or him misunderstanding me over the phone, that could be his last day."

Areas for Improvement

While the overall feedback was positive, the operators suggested some improvements:

- Operator 1 suggested two enhancements to the system: firstly, the inclusion of an "other" field under materials to facilitate manual entry of infrequently used materials, and secondly, the implementation of a feature to record and display the time at which a ladle is emptied. The rationale behind the latter suggestion was that ladles left unused for extended periods, particularly during weather conditions such as rain or snow, may require additional measures before being reintroduced into the production process.
- Operator 2 proposed several enhancements to the system's data management capabilities. These recommendations included the integration of shift team information and melt numbers, as well as the implementation of a feature to facilitate more comprehensive melt data access through Excel-based data transfer. The suggested data expansion encompassed a range of production metrics, including the quantities of various raw materials utilized and fuel consumption figures, among other relevant parameters.

Overall Assessment

Both operators expressed a highly positive view of the new system compared to the current one:

- Operator 1 rated it 5/5, describing the current whiteboard system as outdated and problematic: "I think that whiteboard is ancient and that the information should go from us to the slag truck when the consequences lie largely with them." The operator expressed discomfort with the current situation where only they have an overview of the ladles, and all communication is unidirectional. With the new system, drivers will have better conditions for independent decision-making and information sharing.
- Operator 2 also gave a 5/5 rating, stating, "The accident I was involved in when I was driving slag truck would never have happened with this system," and "I am quite surprised actually that there have not been more accidents than there have been with the current system." Operator 2 also noted the potential for the system to provide valuable production data, leading to a improved final product quality.

In conclusion, the evaluation interviews with the operators revealed a strong positive reception of the new system, with high ratings for its interface, functionality, efficiency, and safety improvements. This positive assessment is quantitatively reflected in the Likert scale ratings, with Operator 1 giving a mean score of 4.5 out of 5 and Operator 2 giving a 4.64 out of 5. The operators' extensive experience in their roles lends significant weight to their positive assessments of the system's potential to prevent risks and improve overall ladle management processes.

1.2.4 Results from Part 2: Slag Truck Drivers

This section presents the results from the evaluation interviews conducted with the two slag truck drivers. The findings are organized based on the key aspects of the system.

User Interface and Functionality

Slag Truck Driver 1 found the interface intuitive and easy to use, rating the intuitiveness as 3 out of 5. The driver commented, "I see difficulties with 'hover' functions and writing notes in a slag truck as you don't have a mouse and keyboard." Regarding the ease of finding and understanding information, the driver rated 4, noting, "Easy to overview once you've had it explained what everything means with colors and such."

The driver appreciated the color-coding system, stating, "It's easy to see with color how far along a solidification is." The system's functionality received high marks, with the driver rating the system's support for necessary ladle handling functions as 4/5 and commenting, "Maybe there should be a popup window if you have driven a ladle from or to the south train after a certain time."

Slag Truck Driver 2 rated the interface's intuitiveness as 4 out of 5, stating, "As long as you've learned the system, it will be really good to use. It's just a matter of learning and getting into it." The driver gave a perfect 5/5 for ease of finding and understanding information, highlighting, "There's a lot of info, significantly more info than we currently have. It looks excellent that you can click/hover over a ladle and see what the content is, how long they have been standing, that things move automatically, and that you can search for ladles and see where they are. I think it looks very good."

Regarding the color-coding and layout, Driver 2 rated it 4/5, noting, "I think it's very clear, then it would have been nice to be able to open/zoom in on different sections such as the trains, solidification area, Furberg garage, etc. Then you can choose between seeing the whole overview image or focusing on smaller parts."

Driver 2 gave the system a perfect 5/5 rating for its support of necessary ladle handling functions, emphasizing, "If it works in practice, it's absolutely a five."

Efficiency Improvements

Slag Truck Driver 1 agreed that the new system would significantly improve efficiency and safety. The driver rated the system's ability to help perform tasks faster/more efficiently as 4/5, estimating that the new system could save them about 15-20 minutes per shift. Driver 1 also noted that a positive aspect of the interface would be "Not having to constantly call operators and ask where to place different ladles" and "knowing which ladles are warm and cold."

Driver 2 also gave efficiency improvements a 4/5 rating, stating, "As long as it doesn't become too much clicking on the screen. But it seems that when everything is as it should be, you won't need to do that." Driver 2 highlighted the system's potential for better planning: "Very good information, and you'll avoid having to physically drive around or call the operators at Blykaldo to check how the situation is."

Driver 2 gave the system a perfect 5/5 rating for its ability to facilitate the planning and follow-up of ladle work, emphasizing the benefit of having a comprehensive overview without the need for physical checks.

Safety Improvements

Driver 1 rated the system's ability to perform tasks more safely as 4/5, noting, "The reason I don't give a five is if the program won't work if, for example, if the network is down." The driver identified several risks that the new system could help prevent, including:

- "In the unlikely event of a driver misplacing a ladle with this system, the next driver will see that it's placed incorrectly."
- Not taking the wrong ladle if they are overflowing (slag level above 225 cm)
- Accidents due to incorrect ladle selection or placement
- Issues with tracking solidification times
- Problems relating to ladles with slag shells

Driver 2 gave the system a perfect 5/5 rating for its ability to perform tasks more safely, stating, "As long as everyone works in the same way and does the same thing, I absolutely believe it will be much safer."

Driver 2 identified several risks that the new system could help prevent:

- Not taking a ladle that contains liquid.
- "In the unlikely event that a slag ladle is incorrectly placed, the next person will see this in the program when they come to the solidification areas"
- "Avoiding taking the wrong ladle and noticing if something is not right without having to call the operators and check against the whiteboard"
- "The ability to mark and add information, preventing the common issue of essential details being forgotten during shift change debriefings, which occur three times a day."
- "For drop/lead ladles, the system's tracking of temperature and time would help tremendously with keeping track of further processing of lead. Also, the ability to mark when a drop ladle is empty can prevent safety risks associated with overfilling."

Driver 2 rated the system's ability to predict risks as 4/5, noting, "I think it looks good, need to test it more in practice to give it a five."

Areas for Improvement

While the overall feedback was positive, driver 1 did suggest some improvements:

- Adding a surface for the milling area
- Possibly adding a surface for when the ladles are to be emptied, an area called "on-ramp."
- The interface asks the drivers to confirm when a ladle is driven to or from the south train

Driver 2 suggested the following improvements:

- Moving storage area under Furberg garage in the interface
- Adding an icon to access other areas, like the milling area
- The ability to expand and collapse sections like train- and solidification areas
- When there are two adjacent gaps, the system should fill the left one first, but only in this situation
- Potentially adding a feature where clicking that a ladle is removed in Fleetskill will then send a signal for automatic movement of the ladle

Overall Assessment

Slag Truck Driver 1 expressed a highly optimistic view of the new system, rating it 4/5 compared to the current one. The driver stated, "A strong four, this system would give me an overview I do not have at the moment. It would also make it easier for the operators, but for my part absolutely, to get this overview of how it actually looks on the solidification area."

Slag Truck Driver 2 also expressed a highly positive view of the new system, rating it 4/5 compared to the current one. The driver stated, "The reason I don't give it a five is that I need more time with the program and see how it works in practice."

Driver 2 highlighted several positive aspects:

- The new system provides a much better overview of the situation
- It eliminates the need for constant communication with operators about ladle placement
- The system makes it easier to detect and prevent potential mistakes
- It provides valuable information about ladle status, including temperature and solidification time

In conclusion, the evaluation interviews with the slag truck drivers revealed a strong positive reception of the new system, with high ratings for its interface, functionality, efficiency, and safety improvements. This positive assessment is quantitatively reflected in the Likert scale ratings, with Slag Truck Driver 1 giving a mean score of 4 out of 5 and Slag Truck Driver 2 giving a mean score of 4.44 out of 5. The drivers' extensive experience in their roles lends significant weight to their positive assessments of the system's potential to prevent risks and improve overall ladle management processes. These high mean scores, coupled with the qualitative feedback, underscore the drivers' confidence in the new system's ability to address current challenges and enhance the efficiency and safety of ladle management operations.

1.2.5 Complete Showcase of User Evaluation Metrics

Figure 3 presents a heatmap visualization of the mean scores across five key categories: (User-friendliness, Functionality, Visualization, Efficiency, and Safety). This visual representation allows for quick identification of each participant's highest and lowest-rated categories, providing an overview of the system's strengths and potential areas for improvement from the users' perspectives. Table 5 presents a comprehensive compilation of individual scores for each question across all categories.

Figure 3: Heatmap of Mean Scores

Table 5: Ratings for All Questions

Question	Operator 1	Operator 2	Driver 1	Driver 2
User-friendliness				
How intuitive is the interface to use?	4	4	3	4
Is the information easy to find and understand?	5	4	4	5
Are there any parts of the interface that are confusing or difficult to navigate?	4	5	4	5

Continued on next page

Table 5 continued

Question	Operator 1	Operator 2	Driver 1	Driver 2
Functionality				
Does the program support all necessary functions for handling ladles?	5	5	4	5
Do all functions work as they should?	4	5	4	5
Visualization and Overview				
Is the information presented in an easy-to-overview way?	4	4	4	4
Do the color coding and layout help you quickly understand the status of each ladle?	5	5	5	4
Is the solidification time clear and easy to understand?	5	5	4	5
Efficiency				
Does the program help the user perform their tasks faster/more efficiently compared to the previous system?	4	4	4	4
Is it easy to update and change information in the system?	4	4	4	4
Does the interface facilitate planning and follow-up of work with ladles?	5	5	3	5
How much time do you think could be saved with the new system?	4	5	4	4
Safety				
Does the program help the user perform their tasks more safely compared to the previous system?	5	5	4	5
How do you perceive the system's ability to predict risks?	5	5	5	4
How much safer do you think the new system is compared to the old one?	4	5	4	4
User Feedback				
How does the user perceive the program compared to the previous system?	5	5	4	4
Overall Mean				
	4.50	**4.69**	**4.00**	**4.44**