Final report

Implementation of Cold Chain Management for Toll Processing Customers

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Executive summary

Background

ACC recognises the importance of cold chain monitoring and the potential benefits as a value add to their customers. By using measured temperature data from throughout product shipment, in conjunction with the shelf-life calculator developed by MLA as implemented automatically by TracknAct, importers will be enabled to understand impact of temperature on product quality.

Furthermore, this project will provide experience and learnings for further improvements to supply chain performance. ACC will also be collecting and using the data to inform future brand owners regarding sending their products to different markets, and delivery models in the customers' selected cold chain.

This is an adoption project; it will monitor product using real-time temperature loggers in collaboration between ACC and its customers.

Objectives

- To review and consider existing technologies and work practice as well as emerging technologies and implications to existing work practices.
- Validate the cold chain management technology with ACC product and customers to cover a range of scenarios, i.e., different countries, air /sea freight etc.
- Quantify the commercial benefit of cold chain management and the potential for shelf-life prediction, as well as the current and potential commercial benefit to the brand owner.
- Country performance using the shelf-life model, simulation of shelf life when entering country, for new customers, manual concept
- Evaluate the utility and performance of the shelf-life model for shipping to different countries and via different transit methods.
- Consider offering real-time cold chain monitoring and automated shelf-live model implementation to new customers in addition to older methodologies (USB temperature data logging & manual shelf-life calculation.)
- Generate a case study on how ACC went with the adoption of new technology.

Methodology

- Purchase 200 loggers from TIVE through KeyData
- Set up red meat industry dashboard with KeyData for data analytics
- Experimental design and logger allocation arranged with customers.
- Measure performance over a period of 6 months
- Provide value proposition

Results/key findings

- Battery Life Management – for configuration between Solo and Beacon devices
- Shelf-Life Algorithm for Highly Marbled Beef – interim solution before shelf life trials completed
- Dashboard and Portal improvements – for red meat industry

Benefits to industry

- The reputation of Australia and of individual Australian brands and producers of chilled beef is further enhanced through in-transit cold chain monitoring, including automated flagging of temperature excursions and the ability to assess their likely impact on arrival shelf life.
- These systems enable shipment routes to be assessed and managed or improved, and the quality of the product (including estimates of microbial count and remaining shelf life) to be provided to customers.
- Sharing this data with supply chain participants enhances awareness of supply-chain issues and of the quality of Australian product and creates capacity to build better relationships whilst maintaining accountability.
- Monitoring and mitigation or elimination of temperature excursions in the supply chain, as well as better assessments of their net effects on microbial count and shelf life, could reduce product rejections and ultimately reduce insurance premiums for those brands and producers who best take advantage of these technologies.

Future research and recommendations

- Improvements to tracker configurations for more frequent data acquisition while maintaining sufficient battery life.
- Shelf-life Algorithms adoption

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1. Background

The Australian red meat industry has several competitive advantages making it strong player in the global market. One of the key advantages is Australia's well-run slaughtering and processing facilities, which yield low microbial counts thus ensuring the safety and quality of the meat. This results in a strong export reputation for Australian beef, enhancing its shelf life and value in the global market.

This high quality and reputation can be further enhanced through real-time cold chain monitoring to ensure that correct temperatures are maintained throughout shipment. Meat and Livestock Australia (MLA) has developed and tested a shelf-life model for vacuum-packed Australian beef and lamb, which uses the initial CFU count as well as periodic temperature measurements throughout the shipment to estimate the shelf life remaining upon arrival. Key findings of this model to-date include an optimal shipping temperature of -0.5°C, as well as an understanding of the effect of excursions above this optimal temperature on the remaining shelf life. This model, in conjunction with real-time cold-chain temperature monitoring, enables estimates of the shelf-life remaining and the impact of any temperature excursions on the product while in transit, and will in turn allow for:

- Identification and rectification of frequent problem areas in cold chain transport routes.
- Maximising shelf life on arrival.
- Further enhancement to the reputation for quality of Australian beef and of specific brands who take advantage of this technology.

ACC recognises the importance of cold chain monitoring and the potential benefits as a value add to their customers. By using measured temperature data from throughout product shipment, in conjunction with the shelf-life calculator developed by MLA as implemented automatically by TracknAct, importers will be enabled to understand impact of temperature on product quality.

Furthermore, this project will provide experience and learnings for further improvements to supply chain performance. ACC will also be collecting and using the data to inform future brand owners regarding sending their products to different markets, and delivery models in the customers' selected cold chain.

This is a pilot adoption project testing various logger settings; it will monitor product using real-time temperature loggers in collaboration between ACC and its customers using the TracknAct service.

2. Objectives

- To review and consider existing technologies and work practices as well as emerging technologies and implications to existing work practices – met successfully with proposed next steps being developed as part of the next stage of the project.
- Validate the cold chain management technology with ACC products and customers to cover a range of scenarios, i.e., different countries, air /sea freight, etc. – successfully met using the TIVE temperature logging Solo's and Beacons.
- Quantify the commercial benefit of cold chain management and the potential for shelf-life prediction and the commercial benefit to the brand owner – successfully met through an internal review of temperature related claims and the cost of implementing temperature loggers over a 12-month period.

- Compare the performance of the cold-chain tracking and shelf-life model in shipments to different countries or geographic regions – successfully met with the beginnings of modelling by country.
- Case study on how ACC went with the adoption of new technology – successfully met with new learnings being reflected on moving forward

3. Methodology

3.1 Stage 1 - Previous

3.1.1 Landscape review of Cold chain management systems

3.1.2 Cost-benefit for implementation of the system

3.1.3 Small pilot trial of the technology

3.1.4 Compare the functionality and user interface of 2 available real-time loggers, Escavox and Tive.

3.2 Stage 2 – Current

3.2.1 Cold Chain Management Implementation Trial

- Purchase of 200 loggers (Solos & Beacons) from TIVE through KeyData TracknAct service
- Configuration of meat industry specific dashboard with KeyData - TracknAct for data analytics
- Experimental design and logger allocation arranged with customers.
- Performance monitored and measured over a period of 6 months
- Partner with 3 clients to provide value proposition

3.2.2 Configuration of Devices

- Each carton contained a Solo and a Beacon, the Solo being between product inside the carton to get a true 'product' temperature, and the Beacon being attached to the cardboard interior of the carton for an 'ambient' temperature.
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  - Solos can be used as a single tracker or a parent tracker. Solos are GPS, Wi-Fi, and cell tower triangulation enabled to provide accurate real-time location data. They include motion sensors, light, temperature, and humidity sensors. Tive estimates, optimal life for a Solo battery is around 90 days and they can be recharged.
  - Beacons report the temperature and proximity to a parent tracker (Solo), which then transmits that data for the whole shipment. Tive estimates optimal battery life on a Beacon to be around three years and they are non-rechargeable.

- Tracking devices were activated and attached to the Tive tracking system via the TracknAct system using the following details:
    - Shipment ID
    - Tracker ID's and Locations
    - Origin
    - Commencement Date
    - Journey legs and transport type
    - Destination
- Once activated, and attached to a shipment, Solo measurement and transmission intervals were configured in the Tive Portal.

4. Results

4.1 Key Findings

4.1.1 Battery Life Management

- At the start of the trial, Solo batteries were found to be depleting much faster than the estimated optimal life suggested by Tive.
- KeyData TracknAct worked with Tive support to determine the cause: the Bluetooth scanning interval on Solos was natively set to five minutes regardless of other tracker configurations and users were unable to see or alter these settings. Tive implemented a feature whereby the Bluetooth scanning interval aligns automatically with Measurement interval.

Outcomes:

- A significant reduction in shipments where the Solo battery dies before reaching destination was observed
    - Prior to the changes to Bluetooth configuration 43.5% shipments reached their destination. After the change to the Bluetooth configuration, 70.8% of shipments reached their destination with 25% still in transit at the time of this report.

Figure 1 Battery performance of Solos: shipments wherein the battery died before reaching the destination or where the shipment successfully Ended, pre- and post- Tive's change to make the Bluetooth scanning frequency automatically sync with the user-controlled measurement frequency.

- Only 4.2% of shipments experienced Solo battery failure since changes were made to the Bluetooth configuration, where previously 56.5% of shipments experienced battery failure. The two that experienced battery failure after the changes were made, was due largely to long time intervals (multiple weeks)

where the product was stored for extended periods prior to dispatch; this points to room for further process improvements.

Battery life tests:

- After the changes to Bluetooth configuration were implemented by Tive, a few tests were conducted to see how Solo batteries performed with different measurement and transmission intervals and Bluetooth settings, to determine the optimum settings.

Results:

- A) Solo with 5-minute measurement / 30-minute transmission intervals and Bluetooth ON:
  - Battery charge decreased from 81% to 0% in about 8.5 days
  - Battery decreases were observed to be notably non-linear
    - Tive customer support advised they were aware and the battery % signal for lithium-battery Solos is not properly calibrated.

- B) Solo with 2-hour measurement / 2-hour transmission and Bluetooth OFF:
  - Battery charge decreased from 86% to 66% over 39 days; the decrease appears linear over this range.

- C) Solo with 2-hour measurement /2-hour transmission and Bluetooth ON:
  - Over the same period, battery charge decreased from 86% to 64%. So only a slightly faster decrease in battery life was recorded compared to having the Bluetooth OFF, at this transmission interval.

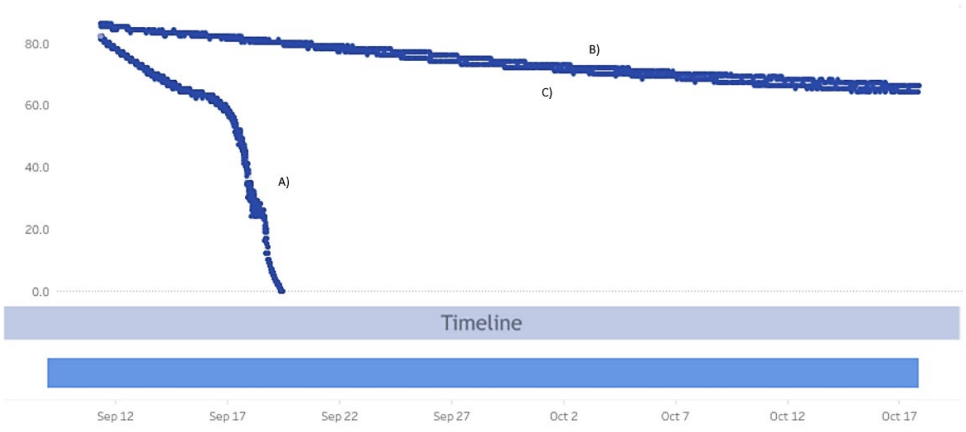


Figure 2 Battery level decrease results across three loggers with varying Bluetooth, measurement, and transmission interval settings.

Experimentation with decreasing measurement intervals continued after this issue was resolved to improve the balance between measurement frequency and battery life. This balance is an important consideration due multiple factors which can significantly change the desired duration of total monitoring:

- significant differences in total shipment durations between road, sea, and air shipments to different destination regions.
- the producers may wish to keep monitoring the product for a variable period after arrival at the shipment destination

On the other hand, increased granularity in measurements allows for more precise and timely identification of high-risk segments in the cold chain (e.g. load-out, freight forwarders), and a more accurate shelf-life estimate due to a more detailed temperature history.

After iteration the following best practice configuration settings were reached:

- Europe: 2-hours measurement /12-hours transmission intervals for sea voyages
- Middle East: 1-hour measurement / 6-hours transmission intervals for sea voyages
- East Asia: 1-hour measurement / 2-hours transmission intervals for sea voyages
- Air Freight: 1-hour measurement / 30-minute transmission intervals
- Domestic: 30-minute measurement / 30-minute transmission intervals

Future work:

- Continue to iterate these values as some measurement and transmission intervals could be further decreased allowing for more granular temperature measurements.
- Investigate the possibility of obtaining more certainty around the length of time the shipment will remain in cold storage prior to commencing the journey. The measurement and transmission intervals currently being used as best practice may result in insufficient battery life if the length of time the shipment spends at Lineage prior to the journey commencing is longer than expected; conversely the intervals could potentially be decreased for better measurement frequency if the time spent at Lineage prior to the journey commencing is reduced.
- Confirm if having Wi-Fi location on for better location accuracy negatively impacts battery drain rate at the measurement and transmission interval settings we have selected as best practice.

4.1.2 Shelf-Life Algorithm for Highly Marbled Beef

- In January and February 2022, KeyData worked with MLA to implement an in-database, automated version of the MLA shelf-life calculator algorithm for Beef and Lamb.
- During the project it became obvious the existing shelf-life algorithm was not designed for highly marbled beef (e.g., Wagyu) and the starting shelf life produced by the implemented algorithm was much higher than expected for such beef.

- The project team collaborated with Long Huynh from MLA to implement an interim solution for providing indicative shelf-life algorithm outputs for highly marbled beef. These revised outputs were useful for the purposes of this project however they have not been validated for highly marbled beef. The following solution was implemented:
    - Alter starting bacterial CFU count to achieve ~120-day starting shelf life.

      Screenshot of modified Shipment input form below; see Figure 3.
- From this point forward, the CFU count will be inaccurate, but the shelf-life decrease should be close enough to be useful.

MLA has expressed interest in working with highly marbled beef producers to trial their shelf-life algorithm more thoroughly for this product type and determine better-tested algorithm parameters.

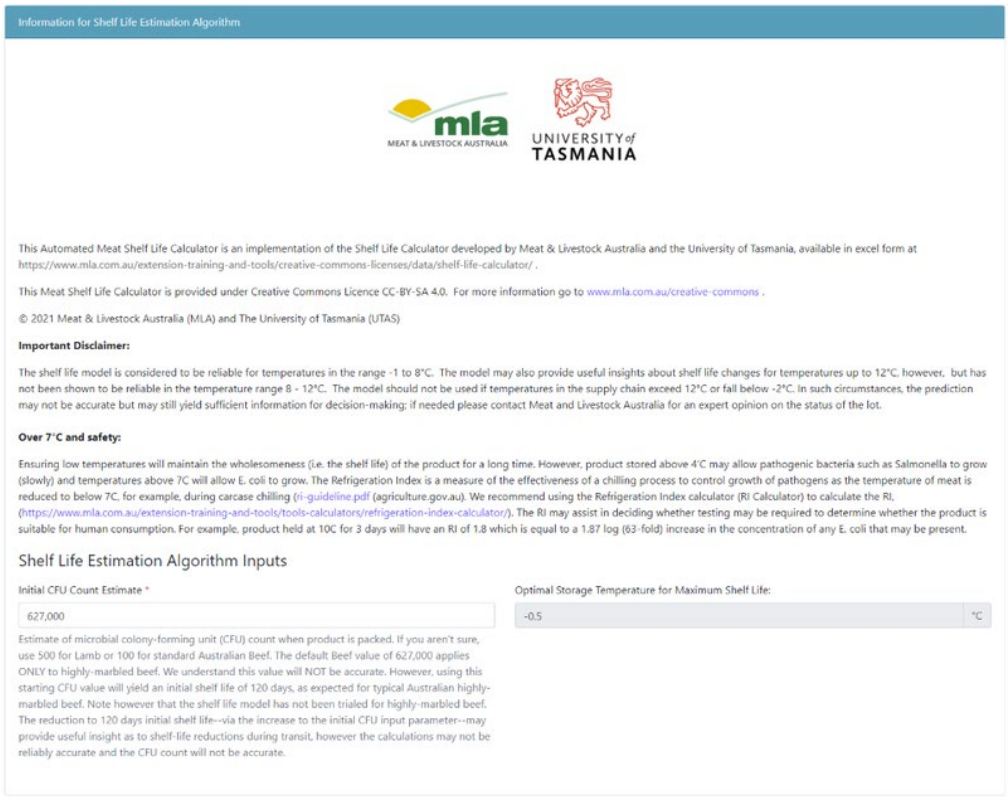


Figure 3 Shelf-Life algorithm entry section of form, modified for highly marbled beef.

4.1.3 Dashboard and Portal improvements

The following key features and further improvements were added to the dashboard during the project please refer to appendix A for more detail:

- Aesthetic improvements on Shipment Summary, Shipment Details, Consignment report dashboard screens to improve design, presentation, and readability;
- Addition of a downloadable/printable Consignment report by shipment with details on trip history, temperature, shelf-life history and shelf-life estimates which can be accessed by selecting a button;
- Enhancements to the Consignment Report including trip leg details such as commenced date, duration in hrs/days, Avg temp, shelf life lost per trip leg in hrs/days and an indicator for the percentage of the shipment wherein the measured temperature was within the desired range;
- Inclusion of an Alerts Icon on the Shipment Details dashboard to enable the user to show all alerts for the selected shipment;
- Provision of a feature on the Shipment Details dashboard where users can set an End of Shipment Date enabling shelf life to be calculated at any point in time up to the removal of the tracking devices from the cartons;
- Filter the Shipment Details dashboard to show latest temperature recording and latest alerts for shipments with no shelf life or show excess shelf life lost and shelf-life remaining headers for shipments with shelf life;
- The addition of a tooltip to show the MLA disclaimer for shelf-life calculations;
- The addition of information icons on all dashboards explaining dashboard contents and shelf-life use instructions.

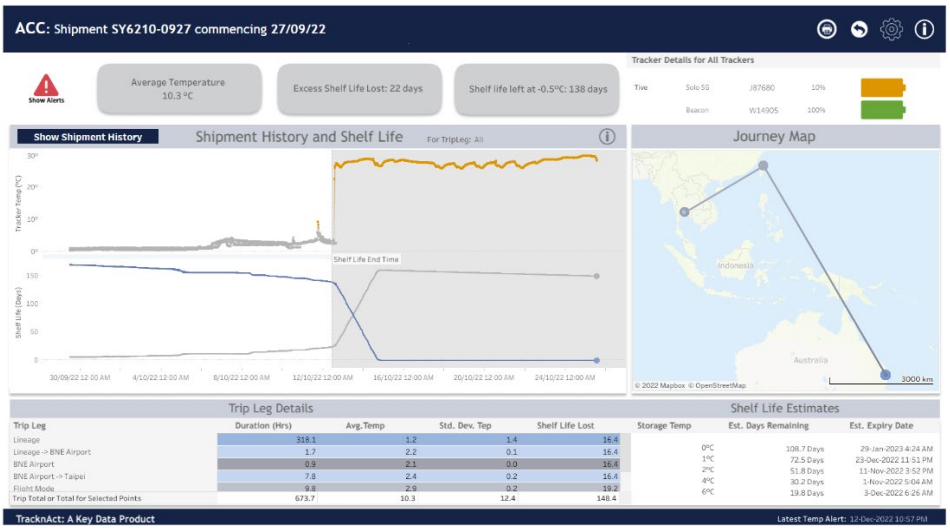


Figure 4a Consignment Report (Shipment end date and Shelf-Life impact calculation separated by leg destination)

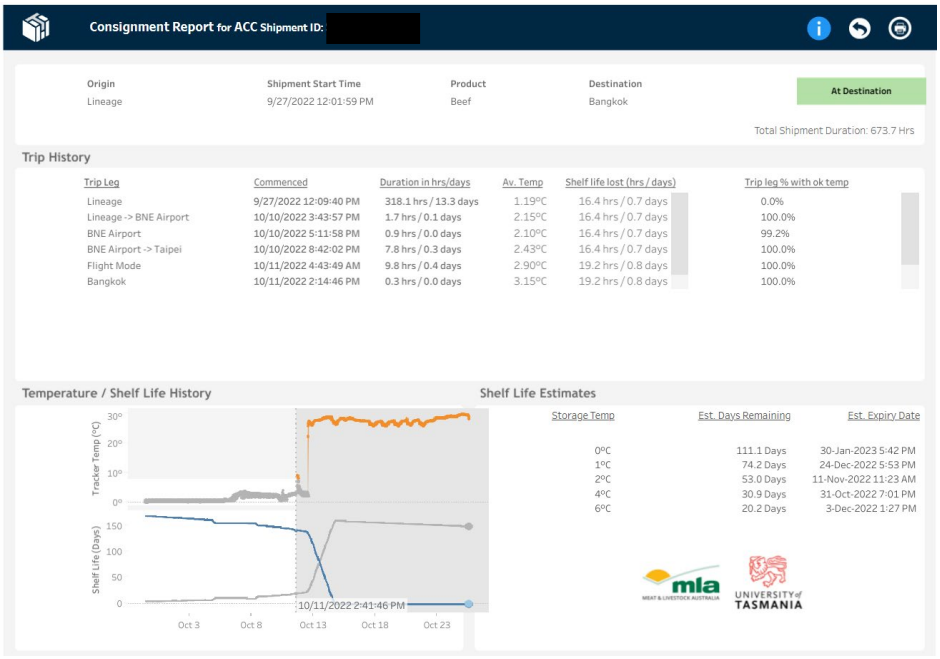


Figure 4b Exportable Consignment Report (Shipment end date and Shelf-Life impact calculation separated by leg destination)

4.1.4 Account Management

- Implementation of access controls for Producer A vs Producer B to ensure each producer could see only their own shipments, and ACC, as the master account, could see both producers' shipments.
- This same setup could be used for future situations where there are clients with sub accounts under a master account, which is in turn a TracknAct client.
- The Tive account for ACC was separated from other TracknAct clients to enable ACC to access tracker details on Tive. This became a requirement due to the issues with Bluetooth configuration affecting the battery life; previously there has been no use case for TracknAct requiring monitoring the battery levels of trackers not currently in shipments. (Added to Tracknact roadmap)
- The project team worked with Tive to understand latest account management features so that as required TracknAct can smoothly grant access to Tive platform (as well as TracknAct) for clients, while maintaining client confidentiality.

4.2 Challenges

During the early stages of the project, delays were encountered due to hesitancy of participants willing to take part in the trial and in setting up the dashboards. The Producers that participated were interested in the potential for high marbling quality beef exports.

The following diagram (Figure 6) shows a screenshot from the Dashboard of a shipment where a Solo logger had inadequate SIM network signal for consistent data transmission. However, the beacon on the shipment had managed to reach another Solo with adequate signal, enabling it to still provide updated

data. This many-to-many transmission scheme for the Beacons, wherein they will transmit data to any reachable Solo, is an advantage in that it will allow another solo with signal to pick up the Bluetooth transmission. TracknAct ensures separation of the client accounts so there would be no cross pollination of data availability between producers with the many-to-many transmissions.

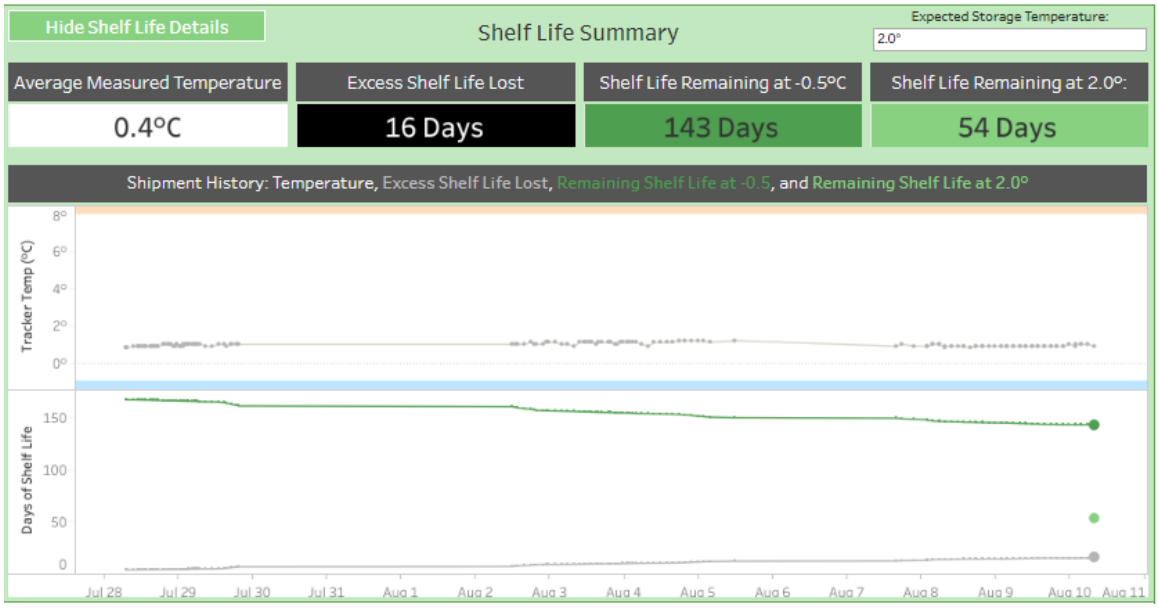


Figure 5 Original Dashboard showing Shelf Life

Figure 6 shows a screenshot of the Dashboard of an early project shipment of Producer A, product destined for the UAE. As highlighted, the Solo had already run flat before the shipment left ACC/Lineage cold storage. This could potentially be due to the lack of cell signal in the cold storage facility, using more battery than normal as the logger is constantly trying to connect. The application of the "best practice" settings for the journey type will address this situation.

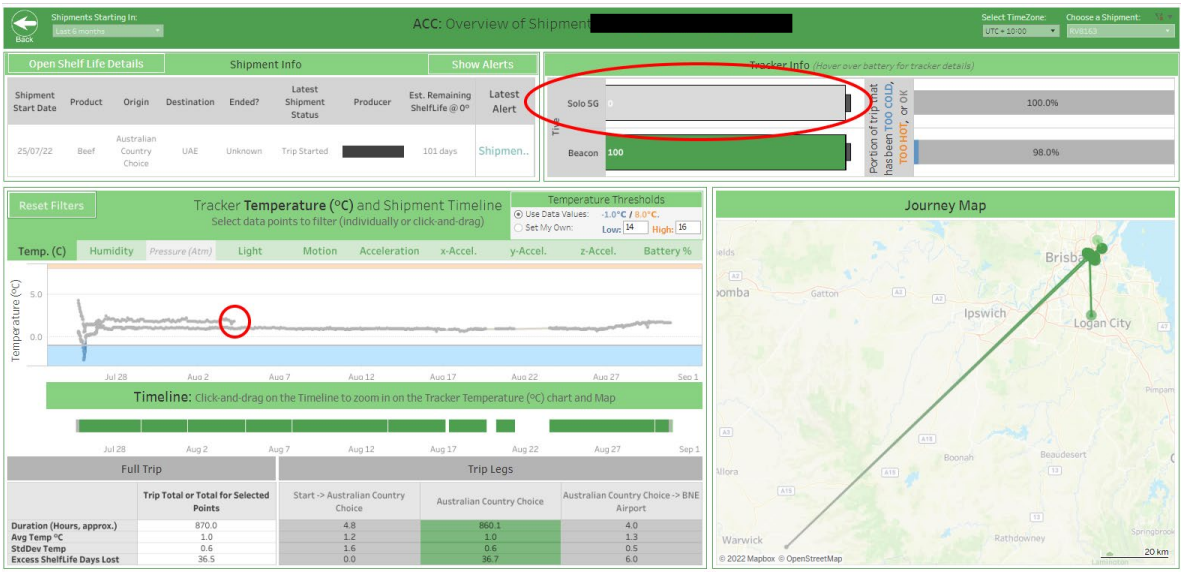


Figure 6 Dashboard of a shipment of Producer A product destined for the UAE

Figure 7 demonstrates challenges in assigning a tracker to a second shipment. Trackers cannot be assigned to a shipment when the shipment they are assigned to has not ended in the system. There are

pros and cons to automatically ending shipments, either by date or end destination. Processors and Producers may wish for a differing analytical view or window into supply chain legs of accountability.

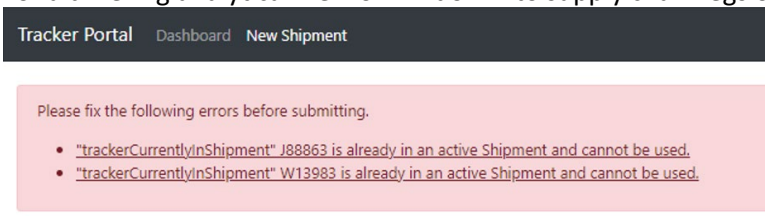


Figure 7 Challenges in assigning a tracker to a second shipment

Figure 8 shows that some orders (the green bars) were still in transit for long haul sea freight at time of report being written.

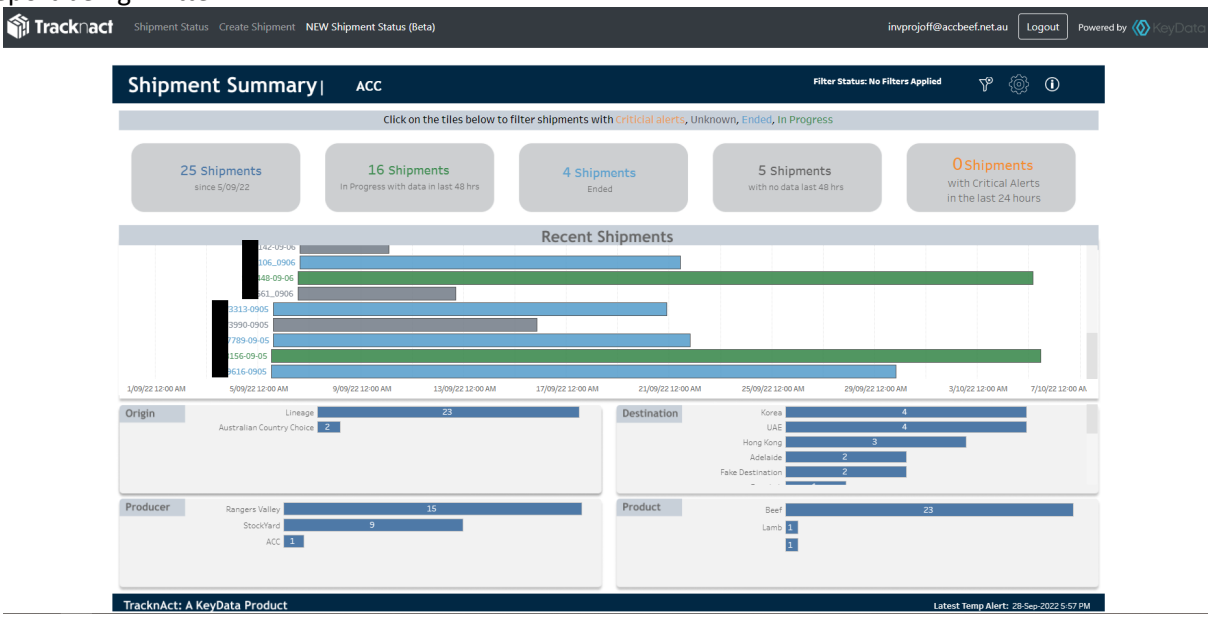


Figure 8 New Beta version of TracknAct for red meat industry; some orders were still in transit at the time of the report being written.

4.2.1 Challenges with freight forwarders

With our cold storage provider not being approved as part of the Known Consignor Scheme, the freight forwarders need to conduct X-Ray scan of all incoming cargo. The live data loggers inside meat cartons were getting detected in this scan, with some cartons not having visual identification of enclosed trackers on outside of carton, causing some extra handling of product. The Freight forwarder requested cartons to have visual identification on the carton outer and to be placed on top of inbound pallets. Cold storage has since received Known Consignor approval so the X-Ray scan should no longer be required at forwarders. Requests have also been received for further information on logger devices used and associated airline / country approvals.

4.3 Successes

The logging is semi-automatic and allows the temperature data and shelf-life information to be automatically calculated. In addition, the dashboard is being customised to suit ACC and red meat industry requirements, such as sharing of shipment information with brand owners and their customers.

Table 1, shows a summary of the last reported battery life on Solos before and after changes to the Bluetooth settings were made. Prior to the changes only 10 shipments were successful; after the changes 34 shipments were successful with 12 still in transit.

Last Reported Battery Life on Solo

Bluetooth Change		Battery Died	Ended	In Progress
Pre Change	Shipments	13	10	
	% of Total Shipments	57%	43%	
Post Change	Shipments	2	34	12
	% of Total Shipments	4%	71%	25%

Table 1 Last Reported Battery Life on Solo

A total of 79 shipments (at time of report), with a variety of transport types, were sent overall, eight of these showed as having beacons and no solos in the system, and one showed as having a solo and no beacon. This may have been due to issues with data entry. At time of installing loggers not all destination information was readily available. This would largely be rectified with data integration to Processor IT ecosystem.

Transport Types	
Air	25
Road	13
Ship	40
TBC	1
Grand Total	79

The Table 2 shows the success of shipments by transportation type once the changes were made to the Bluetooth settings. Significant changes can be seen in most transport types.

Journeys via ship went from five successful shipments and nine unsuccessful, to 14 successful shipments with eight in progress.

Journeys via air went from two successful shipments and four unsuccessful to 16 successful shipments, two still in progress and one unsuccessful.

Tracknact / ACC Shipment Analysis

Count and % of Shipment Success by Bluetooth Scanning

% Shipments Ended | Avg. Min Battery %

Bluetooth Change	Trip End	Main Transport: Ship		Road		Air	
Pre Change	Ended	35.7% (5)	19.4%	100.0% (3)	52.7%	33.3% (2)	53.5%
	Battery Died	64.3% (9)	0.0%			66.7% (4)	0.0%
Post Change	Ended	63.6% (14)	41.1%	57.1% (4)	53.5%	84.2% (16)	51.0%
	In Progress	36.4% (8)	74.6%	28.6% (2)	3.0%	10.5% (2)	73.5%
	Battery Died			14.3% (1)	0.0%	5.3% (1)	0.0%

Table 2 Count and % of Shipment Success by Bluetooth Scanning

The two producers involved in the trial send product Domestically as well as to Asia, Central America, Europe, and the Middle East.

Shipments to Asia

Producer A sent 26 shipments to Asia after the Bluetooth configuration changes, and as at the time of this report all had arrived successfully (19) or were still in progress (7). Prior to the Bluetooth changes five shipments were sent to Asia and but only two successfully arrived before battery depletion.

Producer B sent six shipments to Asia after the Bluetooth changes of which five arrived successfully and one was still in progress as at report time. Prior to the Bluetooth changes four shipments were sent but only two arrived prior to battery depletion.

Shipments to the Middle East

Producer A sent seven shipments to the Middle East after the Bluetooth changes five of these were successful with one shipment still in transit and one having a depleted battery. Prior to the Bluetooth changes of the four shipments sent to the Middle East only one was successful.

Producer B sent four shipments to the Middle East after the Bluetooth changes with three being successful. Prior to the Bluetooth changes four shipments were sent with two of those being successful.

Shipment Destination Success and Battery Life

% Shipments Ended | Avg. Min Battery %

Bluetooth Change	Trip End	Continent	Producer A		Producer B	
Pre Change	Ended	Asia	33.3% (2)	69.0%	50.0% (2)	68.3%
		Australia	100.0% (3)	76.3%		
		Middle East	25.0% (1)	50.5%	50.0% (2)	63.5%
	Battery Died	Asia	66.7% (4)	0.0%	50.0% (2)	0.0%
		Central Ameri..	100.0% (1)	0.0%		
		Europe			100.0% (3)	0.0%
		Middle East	75.0% (3)	0.0%	50.0% (2)	0.0%
Post Change	Ended	Asia	73.1% (19)	71.9%	83.3% (5)	78.4%
		Australia	50.0% (3)	72.4%	100.0% (4)	86.9%
		Central Ameri..	100.0% (1)	84.5%		
		Middle East	71.4% (5)	61.8%	75.0% (3)	76.5%
	In Progress	Asia	26.9% (7)	84.2%	16.7% (1)	91.0%
		Australia	33.3% (2)	51.5%		
		Europe			100.0% (1)	91.0%
		Middle East	14.3% (1)	89.5%	25.0% (1)	89.3%
	Battery Died	Australia	16.7% (1)	0.0%		
		Middle East	14.3% (1)	0.0%		

Table 3 Shipment Destination Success and Battery Life

After addressing the initial battery life issues caused by the Bluetooth scanning interval configuration issues, almost all subsequent shipments were successfully completed with adequate battery life and temperature data through to the destination; only two shipments had in-transit battery failures after this change, and both were due to unexpectedly long periods spent at the initial freight forwarder after tracker insertion before the shipment commenced.

Figure 9 The new version of the TracknAct dashboard with streamlined design. Dark green bars show shipments in progress, while light blue bars show in-progress shipments and their duration.

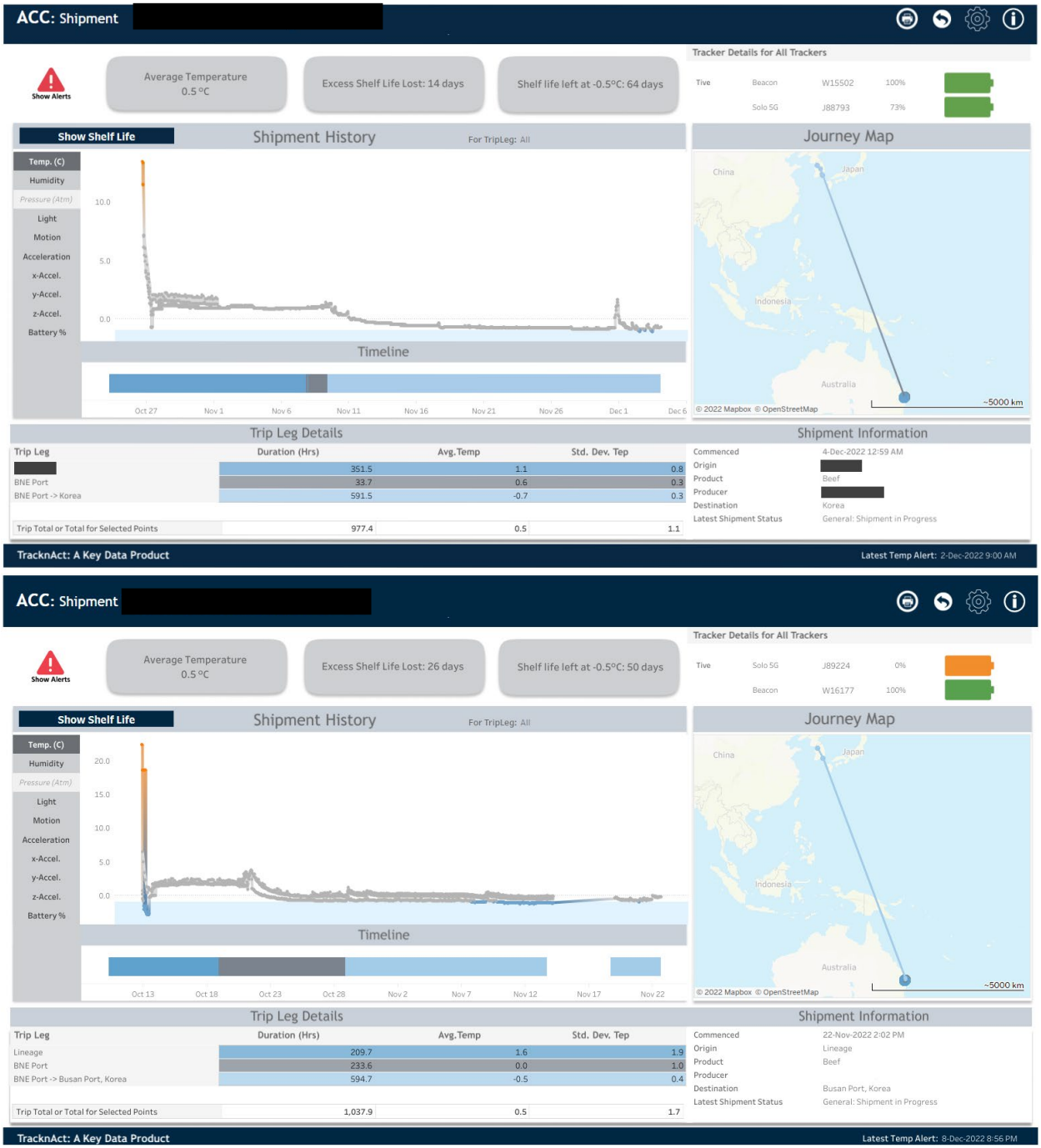


Figure 10 Successful completed trips to Korea

Collaborative project and product road map discussions between ACC, Tive, and TracknAct informed and contributed to TIVEs release updates:

- **Automatically share shipments with carriers:** You can now easily share shipments with customers to keep them up to date on any in-transit shipment issues.
- **Bluetooth is now enabled for beacons:** When a Solo tracker's measurement interval is changed, the Bluetooth update interval automatically updates to match. This improves a beacon's location accuracy and preserves battery life.

5. Conclusion

5.1 Key findings

In-transit cold chain monitoring and on-the-fly shelf-life calculations can be of significant utility to producers and brands. However further work is needed to improve processes to enhance useability, better manage battery life vs. data frequency, simplify the workload for both individual producers and processors with regards to data entry and tracker device management, and enhance the utility of the MLA shelf-life algorithm to a wider variety of Australian chilled beef.

- The project validated the emerging technology and set configuration standards for the various transport and country options to allow for good management of battery life and data capture frequency. In particular, Tive technologies were proven to be suitable for in-transit cold-chain monitoring for this industry.
- The combination of SIM-enabled Solos and Bluetooth-enabled Beacons allowed for more trackers per shipment at a reduced cost compared to using multiple SIM-enabled devices per shipment. However, during the project, issues where the Bluetooth significantly negatively affected battery performance were identified and addressed.
- Providing the capability for the final shelf life to be calculated at different times during the shipment until the point where trackers are removed from the cartons, can empower producers to view the temperature effects of their entire supply chain up until delivery, whereas the producer or freight forwarder in turn could focus on only the portion of the shipment for which they are responsible.
- To streamline processes, create efficiency and ensure consistency of data insights derived and maximise benefits to Processor, Producer, and Retailers wider data integration options with current on-floor and traceability solutions should be explored.

5.2 Benefits to the industry

- The reputation of Australia and of individual Australian brands and producers of chilled beef is further enhanced through in-transit cold chain monitoring, including automated flagging of temperature excursions and the ability to assess their likely impact on arrival shelf life.
- These systems enable shipment routes to be assessed and managed or improved, and the quality of the product (including estimates of microbial count and remaining shelf life) to be provided to customers.
- Sharing this data with supply chain participants enhances awareness of supply-chain issues and of the quality of Australian product and creates capacity to build better relationships whilst maintaining accountability.
- Monitoring and mitigation or elimination of temperature excursions in the supply chain, as well as better assessments of their net effects on microbial count and shelf life, could reduce product rejections and ultimately reduce insurance premiums for those brands and producers who best take advantage of these technologies.

6. Future research and recommendations

Future Research:

- Improvements to tracker configurations for more frequent data acquisition while maintaining sufficient battery life:
    - Improve process management to enable better estimation of the time shipments will spend at the initial freight forwarder before shipment.
    - Alternately, change the process such that the Tive Solo trackers (the ones with shorter battery life) are placed in the cartons at the end of their time spent at the initial freight forwarder, rather than prior to that period. The temperature while at the freight forwarder could still be monitored by means of having a Tive Beacon in each tracked carton, which could transmit its temperature data via Bluetooth connection to one of several static Solo trackers which could be statically placed strategically around the initial freight forwarder or storage warehouse for this purpose.
    - In either case, the duration of the required Solo battery life for the shipment's completion can be more accurately forecasted—and in the latter case also shortened—due to reducing or removing the large variability of the time spent at the initial freight forwarder before the start of transit.
    - In combination with the above, further research in the form of iteration over tracker measurement and transmission frequency settings could allow for better "best practice" settings depending on transport mode (road / air / sea freight) and destination country or geographical region (e.g., domestic, Europe, South-East Asia, Japan, North America.)
    - Finally, for even better battery management for lengthier sea freight voyages it may prove fruitful to investigate automated changes of the transmission frequency. This should ideally be more frequent when the shipment is on land and can transmit via the SIM network but could be automatically made less frequent when the shipment is at sea to preserve battery life. This change could potentially be triggered via geofencing proximity to the departure and arrival ports.

  - Connectivity to the onboard network for sea freight shipments may also prove to be a potential future move.
  - Further automation and process improvement of the shipment data ingestion and tracking process can be achieved via integration with existing ACC and producer IT platforms and solutions.

- Shelf-life Algorithms adoption
  - The MLA shelf-life model has been trained and tested on non-highly marbled vacuum-pack chilled Australian beef. However, sufficient research has not yet been done to determine optimal model parameters for highly marbled Australian vacuum-pack chilled beef (including Wagyu), which has a shorter shelf life for the same initial CFU count due to the increased fat content. Scope exists to extend the utility of the shelf-life algorithm through further trials with a wider range of meat including but not limited to highly marbled Australian beef
  - Meanwhile further trials targeting producers of non-highly marbled Australian beef would allow for better testing and adoption of the existing shelf-life algorithm implementation.

Although there were numerous challenges during the pilot trial it was successful. The trial only involved a small group of brand owners to test the desirability and feasibility of the technology. The current process is manual and requires individual brand owners to populate the shipment information.

ACC proposed the project move to stage 2 which would involve:

- a short commercial trial (6 months)
- automation, auto scanning and filling of shipments (currently manual)
- Small shelf life trial on Wagyu and matching with the shelf life calculator to determine the accuracy of the current shelf life prediction
- Trial temperature recording labels which does not need a battery

7. Appendix A: TracknAct Platform Improvements

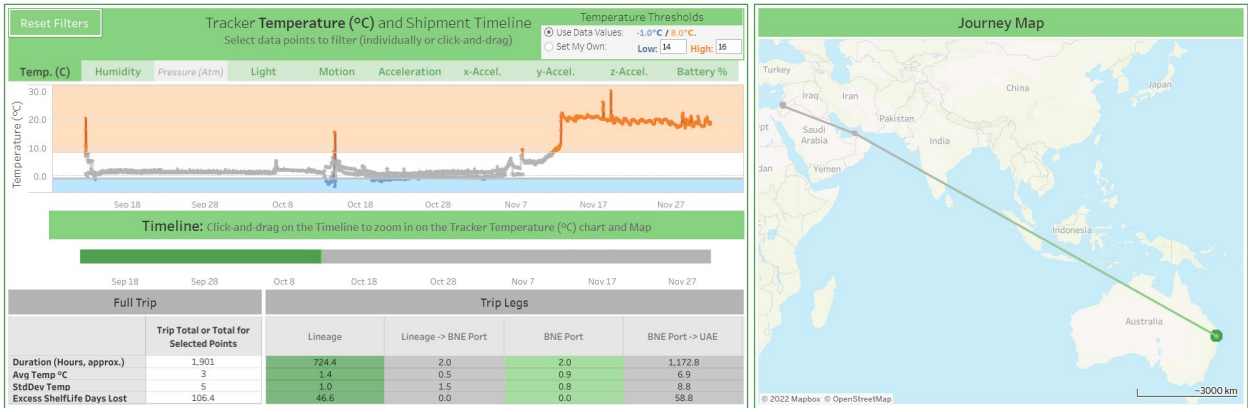
The following key features and further improvements were added to the dashboard during the project

- Aesthetic improvements on Shipment Summary, Shipment Details, Consignment report dashboard screens to improve design, presentation, and readability and maximise the use of screen space
- Addition of exportable Consignment report
- Improvements to the readability of the Gantt chart and simplification of information on Gantt chart hover overs
- Modification of the overall colour palette to be colour blind friendly
- Add the ability to clear high-level filters with one click on the Summary page
- Include a Timestamp for the Latest Temperature on the Shipment Details dashboard.
- Include capability within the Shipment Details dashboard for the user to focus on selected points in the Metric and Journey Map and the ability to filter other relevant details for those points.
- Include an Alerts Icon on the Shipment Details dashboard the user can select to show all alerts for the selected shipment
- Provide a feature on the Shipment Details dashboard where users can set an End of Shipment Date through Settings which can then be used for shelf-life calculations, allowing the shelf life to be calculated as of any point in time up to the removal of the temperature trackers from the cartons.
- Include the ability on the Shipment Details dashboard for users to highlight Shipment History and Journey Map points based on trip leg hover
- Filter the Shipment Details dashboard to show the latest temperature recording and latest alerts for shipments with no shelf life or show excess shelf life lost and shelf-life remaining headers for shipments with shelf-life
- Addition of a downloadable/printable Consignment Report with details on trip history, temperature, shelf-life history, and shelf-life estimates which can be accessed by selecting a button
- Enhancements to the Consignment Report including trip leg details such as commenced date, duration in hrs/days, Avg temp, shelf life lost per trip leg in hrs/days, and ‘trip leg % with OK temp’.
- The addition of a tooltip to show the disclaimer for shelf-life calculations

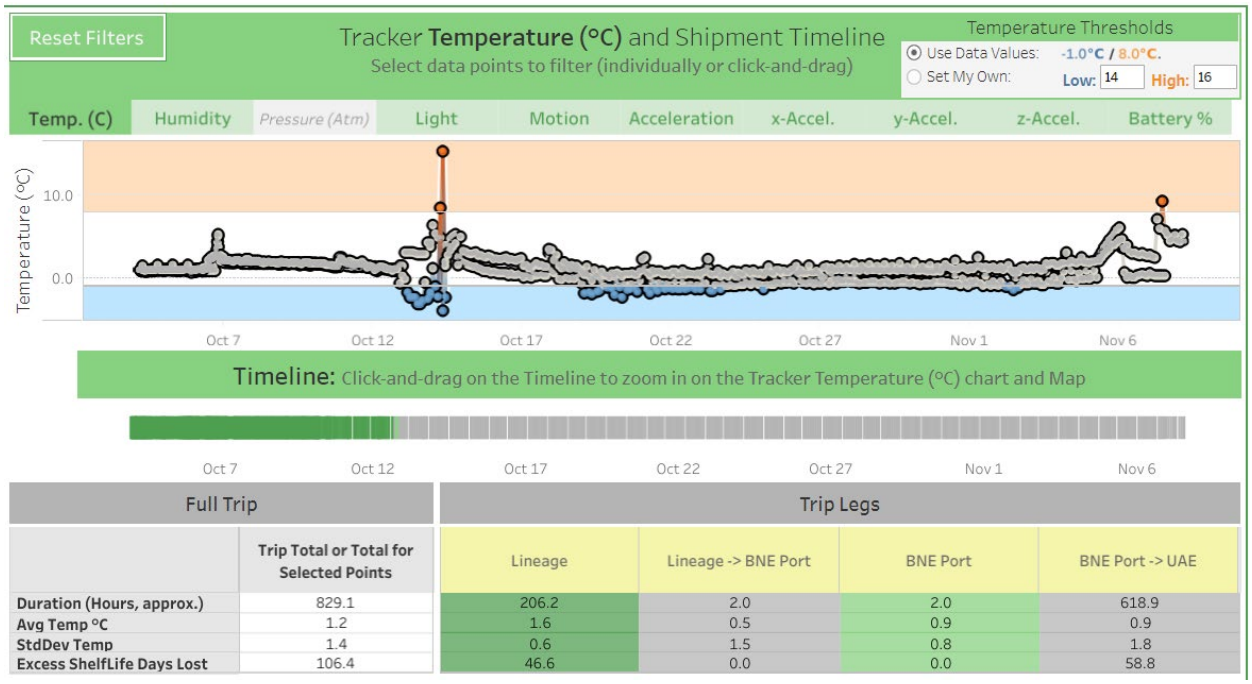
The addition of information icons on all dashboards to explain the contents and use of the dashboard.

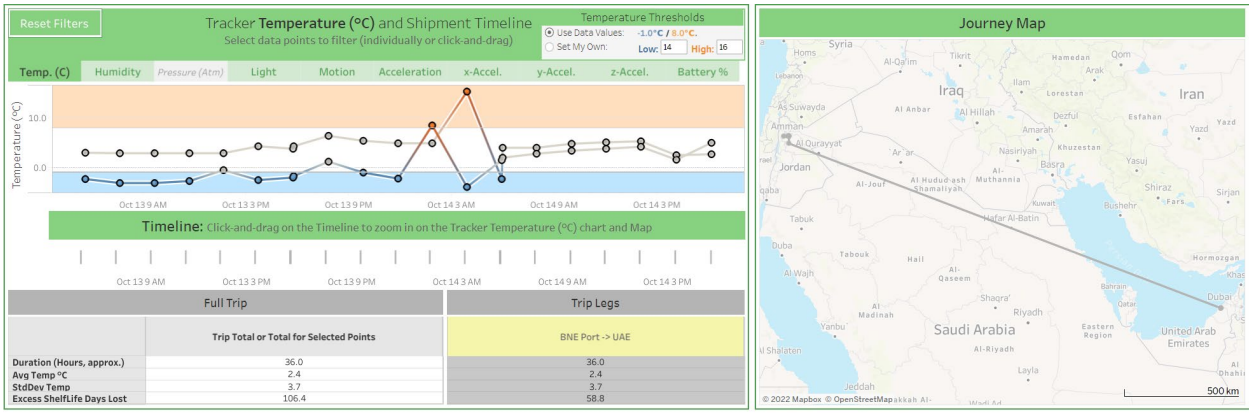
8. Appendix B: Identifying specific temperature excursions accountability

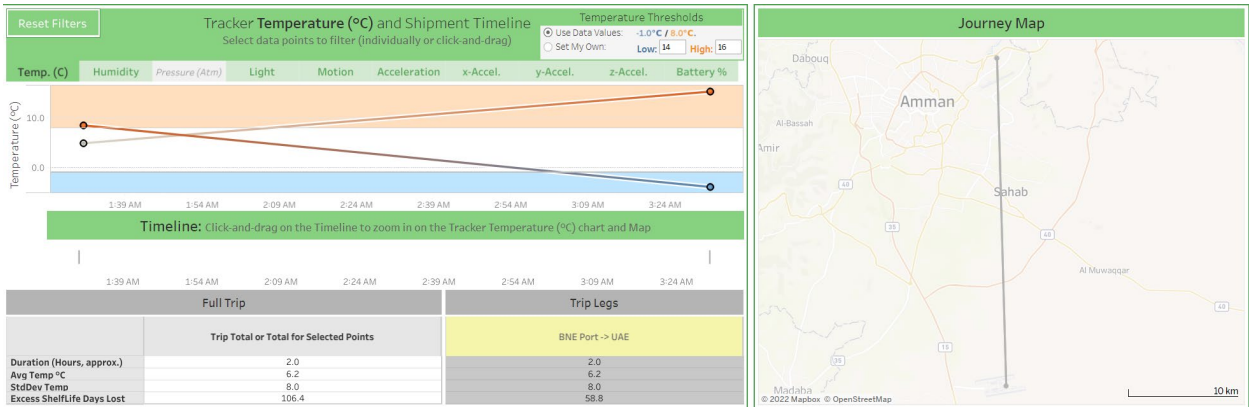
Below are some visual examples of homing in via the dashboard on specific excursions of concern, identifying leg, location, duration, and accountability.

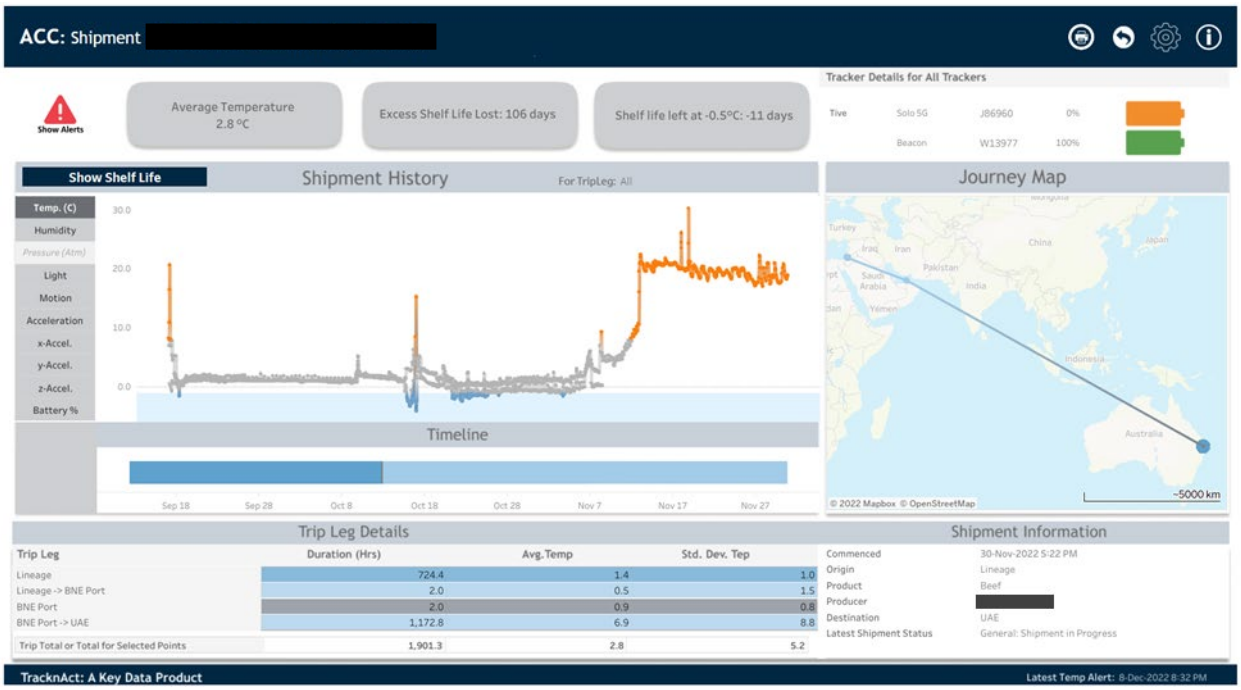


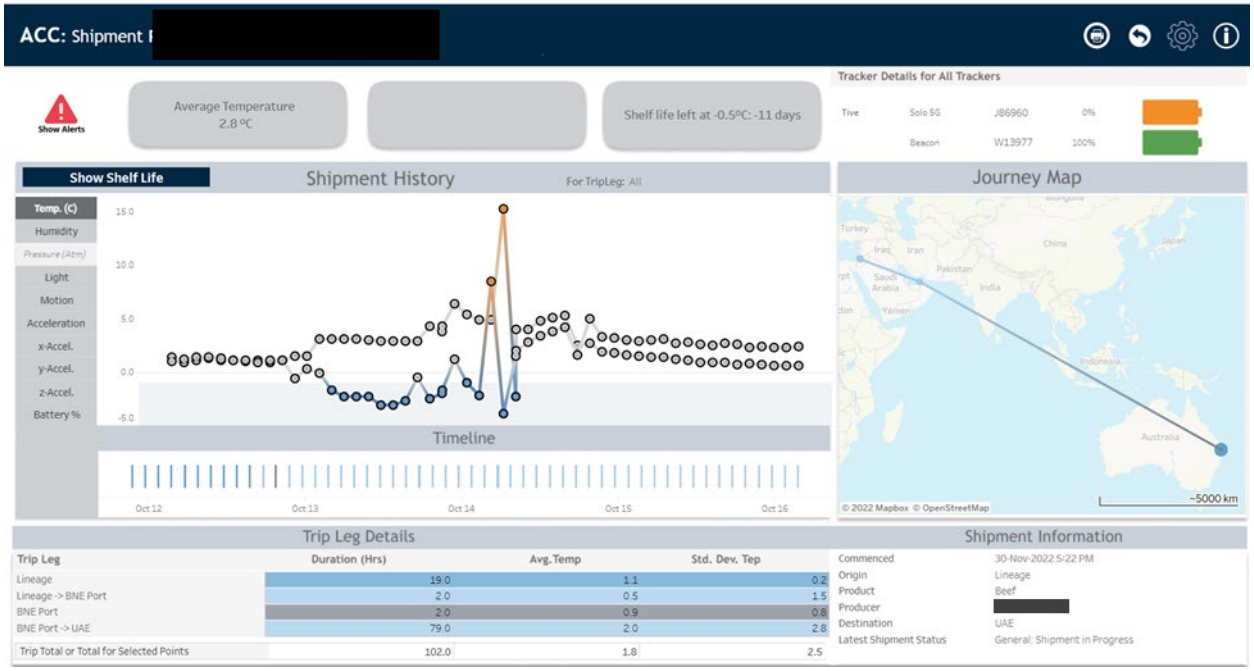
ACC: Overview of Shipment [redacted]

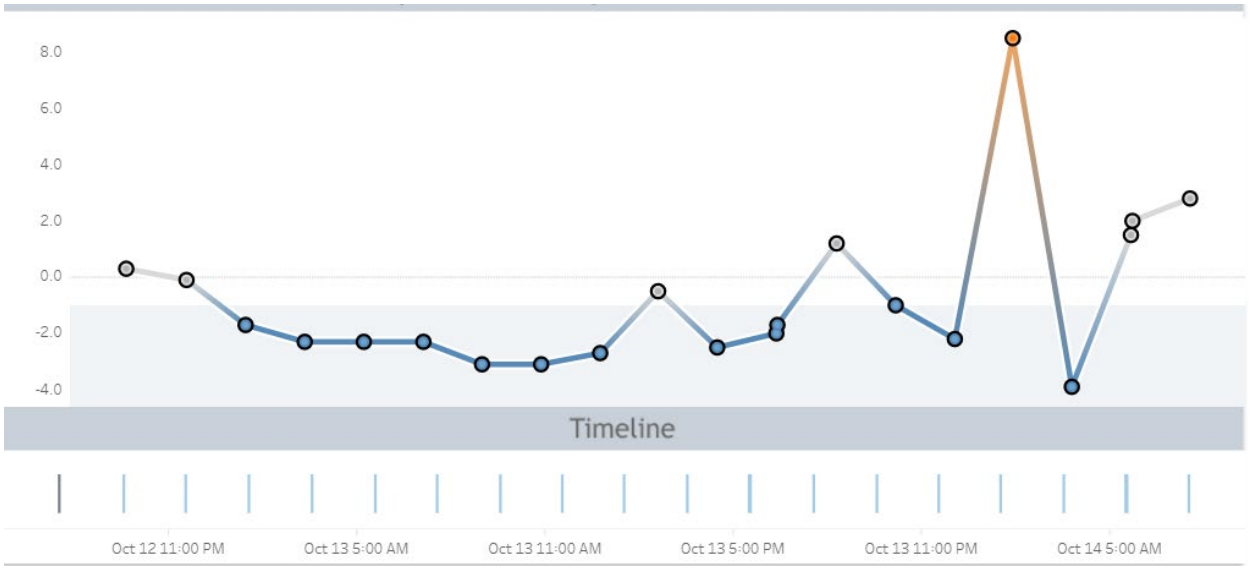


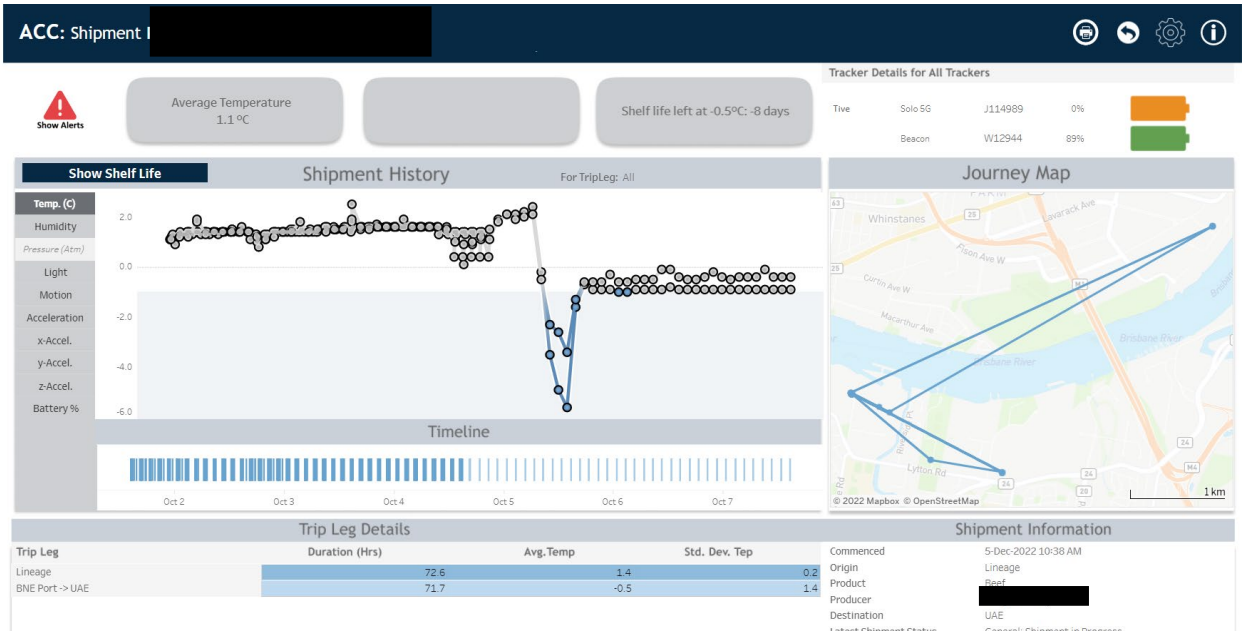

Reset Filters
Tracker Temperature (°C) and Shipment Timeline
Select data points to filter (individually or click-and-drag)
Temperature Thresholds
Use Data Values: -1.0°C / 8.0°C.
Set My Own: Low: 14 High: 16
Temp. (C) Humidity Pressure (Atm) Light Motion Acceleration x-Accel. y-Accel. z-Accel. Battery %
Temperature (°C)
10.0
0.0
Oct 13 9 AM Oct 13 3 PM Oct 13 9 PM Oct 14 3 AM Oct 14 9 AM Oct 14 3 PM
Timeline: Click-and-drag on the Timeline to zoom in on the Tracker Temperature (°C) chart and Map
Full Trip
Trip Legs
Trip Total or Total for Selected Points
BNE Port -> UAE
Duration (Hours, approx.) 36.0 36.0
Avg Temp °C 2.4 2.4
StdDev Temp 3.7 3.7
Excess ShelfLife Days Lost 106.4 58.8
Journey Map
Syria
Iraq
Iran
Jordan
Saudi Arabia
United Arab Emirates
© 2022 Mapbox © OpenStreetMap
500 km

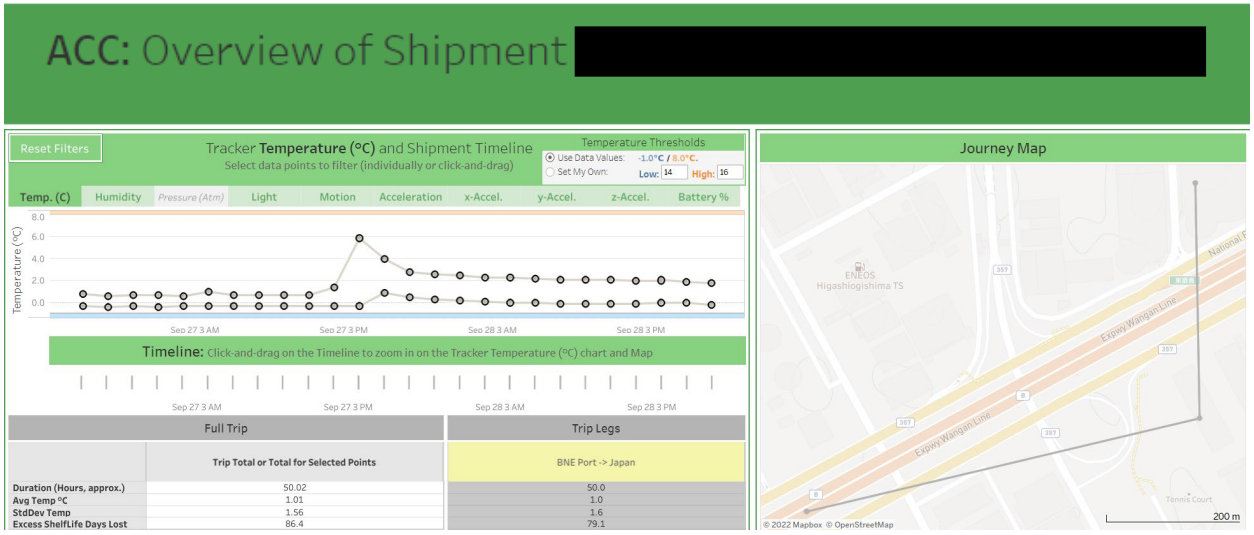

Reset Filters
Tracker Temperature (°C) and Shipment Timeline
Select data points to filter (individually or click-and-drag)
Temperature Thresholds
Use Data Values: -1.0°C / 8.0°C.
Set My Own: Low: 14 High: 16
Temp. (C) Humidity Pressure (Atm) Light Motion Acceleration x-Accel. y-Accel. z-Accel. Battery %
Temperature (°C)
10.0
0.0
1:39 AM 1:54 AM 2:09 AM 2:24 AM 2:39 AM 2:54 AM 3:09 AM 3:24 AM
Timeline: Click-and-drag on the Timeline to zoom in on the Tracker Temperature (°C) chart and Map
Full Trip
Trip Legs
Trip Total or Total for Selected Points
BNE Port -> UAE
Duration (Hours, approx.) 2.0 2.0
Avg Temp °C 6.2 6.2
StdDev Temp 8.0 8.0
Excess ShelfLife Days Lost 106.4 58.8
Journey Map
Amman
Sahab
Al Muwaqqar
© 2022 Mapbox © OpenStreetMap
10 km

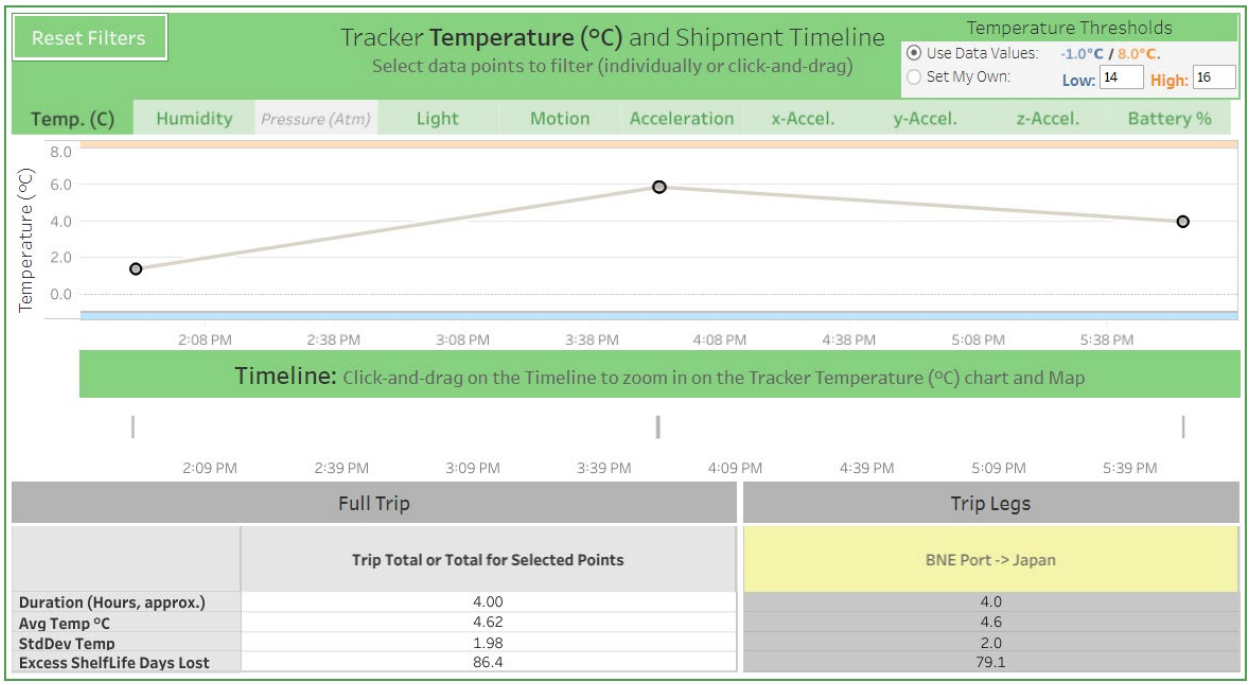

ACC: Shipment [redacted]
Show Alerts
Average Temperature 2.8 °C
Excess Shelf Life Lost: 106 days
Shelf life left at -0.5°C: -11 days
Tracker Details for All Trackers
Tive Solo 5G J86960 0%
Beacon W13977 100%
Show Shelf Life
Shipment History
For TripLeg: All
Temp. (C)
Humidity
Pressure (Atm)
Light
Motion
Acceleration
x-Accel.
y-Accel.
z-Accel.
Battery %
30.0
20.0
10.0
0.0
Timeline
Sep 18 Sep 28 Oct 8 Oct 18 Oct 28 Nov 7 Nov 17 Nov 27
Journey Map
China
Japan
India
Pakistan
Australia
Indonesia
© 2022 Mapbox © OpenStreetMap
~5000 km
Trip Leg Details
Trip Leg Duration (Hrs) Avg.Temp Std. Dev. Tep
Lineage 724.4 1.4 1.0
Lineage -> BNE Port 2.0 0.5 1.5
BNE Port 2.0 0.9 0.8
BNE Port -> UAE 1,172.8 6.9 8.8
Trip Total or Total for Selected Points 1,901.3 2.8 5.2
Shipment Information
Commenced 30-Nov-2022 5:22 PM
Origin Lineage
Product Beef
Producer [redacted]
Destination UAE
Latest Shipment Status General: Shipment in Progress
TracknAct: A Key Data Product
Latest Temp Alert: 8-Dec-2022 8:32 PM


ACC: Shipment [redacted]
Show Alerts
Average Temperature
2.8 °C
Shelf life left at -0.5°C: -11 days
Tracker Details for All Trackers
Tive
Solo 5G
J86960
0%
Beacon
W13977
100%
Show Shelf Life
Shipment History
For TripLeg: All
Temp. (C)
Humidity
Pressure (Atm)
Light
Motion
Acceleration
x-Accel.
y-Accel.
z-Accel.
Battery %
15.0
10.0
5.0
0.0
-5.0
Timeline
Oct 12
Oct 13
Oct 14
Oct 15
Oct 16
Journey Map
Turkey
Iraq
Iran
China
Japan
Pakistan
Saudi Arabia
India
Yemen
Indonesia
Australia
© 2022 Mapbox © OpenStreetMap
~5000 km
Trip Leg Details
Trip Leg
Duration (Hrs)
Avg.Temp
Std. Dev. Tep
Lineage
19.0
1.1
0.2
Lineage -> BNE Port
2.0
0.5
1.5
BNE Port
2.0
0.9
0.8
BNE Port -> UAE
79.0
2.0
2.8
Trip Total or Total for Selected Points
102.0
1.8
2.5
Shipment Information
Commenced
30-Nov-2022 5:22 PM
Origin
Lineage
Product
Beef
Producer
[redacted]
Destination
UAE
Latest Shipment Status
General: Shipment in Progress


8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
Timeline
Oct 12 11:00 PM
Oct 13 5:00 AM
Oct 13 11:00 AM
Oct 13 5:00 PM
Oct 13 11:00 PM
Oct 14 5:00 AM


ACC: Shipment [redacted]
Show Alerts
Average Temperature
1.1 °C
Shelf life left at -0.5°C: -8 days
Tracker Details for All Trackers
Tive
Solo SG
J114989
0%
Beacon
W12944
89%
Show Shelf Life
Shipment History
For TripLeg: All
Temp. (C)
Humidity
Pressure (Atm)
Light
Motion
Acceleration
x-Accel.
y-Accel.
z-Accel.
Battery %
Timeline
Oct 2
Oct 3
Oct 4
Oct 5
Oct 6
Oct 7
Journey Map
Whinstanes
© 2022 Mapbox © OpenStreetMap
1 km
Trip Leg Details
Trip Leg
Duration (Hrs)
Avg.Temp
Std. Dev. Tep
Lineage
72.6
1.4
0.2
BNE Port -> UAE
71.7
-0.5
1.4
Shipment Information
Commenced
5-Dec-2022 10:38 AM
Origin
Lineage
Product
Beef
Producer
[redacted]
Destination
UAE


ACC: Overview of Shipment [redacted]
Reset Filters
Tracker Temperature (°C) and Shipment Timeline
Select data points to filter (individually or click-and-drag)
Temperature Thresholds
Use Data Values: -1.0°C / 8.0°C.
Set My Own: Low: 14 High: 16
Temp. (C)
Humidity
Pressure (Atm)
Light
Motion
Acceleration
x-Accel.
y-Accel.
z-Accel.
Battery %
Temperature (°C)
Sep 27 3 AM
Sep 27 3 PM
Sep 28 3 AM
Sep 28 3 PM
Timeline: Click-and-drag on the Timeline to zoom in on the Tracker Temperature (°C) chart and Map
Full Trip
Trip Legs
Trip Total or Total for Selected Points
BNE Port -> Japan
Duration (Hours, approx.)
50.02
50.0
Avg Temp °C
1.01
1.0
StdDev Temp
1.56
1.6
Excess ShelfLife Days Lost
86.4
79.1
Journey Map
ENEOS Higashiogishima TS
Expwy Wangan Line
© 2022 Mapbox © OpenStreetMap
200 m



Full Trip		Trip Legs
	Trip Total or Total for Selected Points	BNE Port -> Japan
Duration (Hours, approx.)	4.00	4.0
Avg Temp °C	4.62	4.6
StdDev Temp	1.98	2.0
Excess ShelfLife Days Lost	86.4	79.1