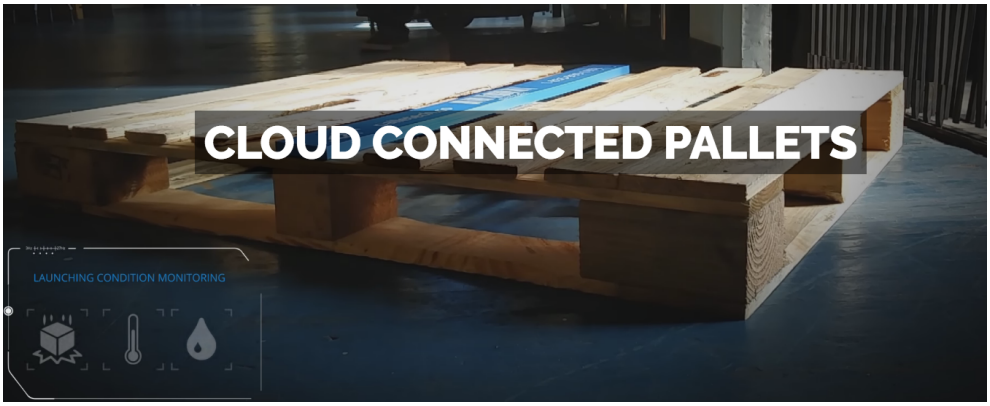
Andrew Schneer
MindSumo
Kaneka
Tote Tracking Solution
12 / 15 / 2016

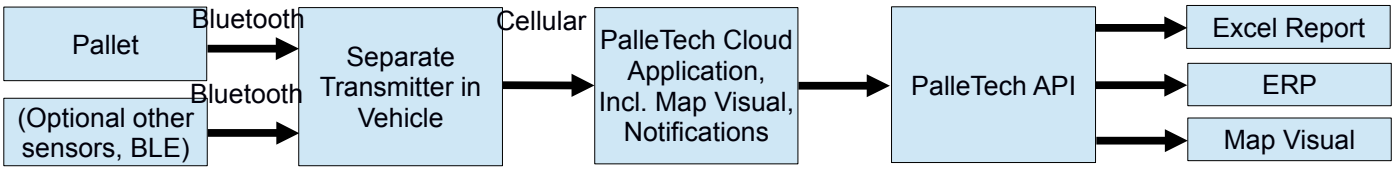
Primary Solution

The most promising long-term solution for tracking Kaneka's totes is to use an asset tracking service like **PalleTech.** PalleTech is a company is San Francisco that leases "smart" shipping pallets to customers to help them track their assets throughout their distribution chains. Below is an overview of PalleTech's system as well as a link to their website.



Courtesy PalleTech - http://palletech.co/index.html

This flowchart outlines how the PalleTech system works:



Each pallet consists of a standard wooden shipping pallet with a "smart" center plank swapped in (blue plank shown in the image above). The center plank contains sensors, a battery, and communication electronics which track data about the asset on the pallet. The PalleTech pallets require a central transmitter to be located in the vehicle where the pallets reside. The pallets relay their data to the transmitter, which then uploads the data to the cloud.

PalleTech delivers pallets to Kaneka's facility in Michigan. When the totes leave the Kaneka warehouse in Michigan, each one will be loaded onto a "smart" pallet, just as they are loaded onto normal wooden pallets now. Each tote will stay with the same pallet throughout its 2-3 month journey around North America, and it can be easily moved, loaded, and unloaded using a standard forklift. Throughout its journey, each tote's corresponding pallet will send the measured pallet weight and GPS location to a PalleTech's cloud server, where Kaneka employees can easily access it at any time. The pallets can either be picked up by PalleTech at the final destination, or brought brought back to Michigan to restart the shipping cycle.

Features:

- Pallet is capable of measuring the following:
  - Geographic location
  - Temperature
  - Atmospheric pressure
  - Shocks
  - Drops
  - Tilts
- Cloud software and mobile app included, which both have **map interface** for tracking pallet locations
- Real-time notifications triggered by sensor data (for example, get an email if the pallet is dropped or reaches a certain temperature)
- External sensors that are bluetooth enabled can be added to the system and can use the PalleTech transmitter as a gateway for uploading data to the cloud
- Use the same pallets continuously for a closed-loop shipping cycle
- PalleTech APIs available for customizing how the data is handled in the cloud

Advantages	Disadvantages
• All-in-one solution • Ready to use immediately • No maintenance for Kaneka • Pallet has 4 year battery life • Transmitter included with subscription • 3 mile range between pallets and transmitter • Data uploaded to cloud via cellular network, so data can transmit from anywhere, including inside a truck or train • No risk to try, cancel service anytime • No up-front cost • 162 pallets is a small amount for PalleTech, so they can easily support the demand	• Central transmitter required in addition to the pallets, but provided by PalleTech • Transmitter currently requires vehicle power by plugging into power outlet • Currently no weight measurement • Lead time for pallets is 2-3 months • Unclear whether or not cellular communication will work outside the U.S. • Unclear which pallet sizes are available (might be too large for one tote) • Fairly expensive, best for low volume and high-value assets

Getting Around the Shortcomings:

Although the transmitter is NOT currently self-powered, PalleTech plans to **add this feature in Q1 of 2017.** They will add a battery pack to the transmitter which should easily last the 2-3 months that it takes to complete one shipping cycle. When this feature is added, the transmitter will have to stay with the group of totes throughout the duration of a shipment cycle. Depending on how the totes are distributed during shipments, more than one transmitter might be required. If a significant number of transmitters are required, Kaneka will have to negotiate with PalleTech to get additional transmitters. Usually they assume that a customer will only need one transmitter for a single shipment, because all pallets in a single shipment will be in the same truck within range of one transmitter.

Although PalleTech does cannot currently measure the weight of the asset loaded on the pallet, they are planning to **add this functionality sometime in 2017.** There is some risk with this promise because presumably the technology has not yet been developed. PalleTech is a new company,

having been in business for only two years, and they are planning to scale up significantly in 2017 by manufacturing 1 million additional pallets and doing an IPO (this information comes directly from the company's founder). It is possible that if the weight-sensing technology winds up being more difficult to implement than expected, PalleTech might delay implementing it considering how many other plans they already have for 2017 as a company. If this happens, there are other options for measuring the weight using third party sensors. As long as they are bluetooth enabled, they can be used with the PalleTech system and their data will be sent to the cloud via the PalleTech transmitter.

Cost:

PalleTech uses a subscription model for pricing. They loan out the pallets on a per-trip, per-pallet basis. When a customer orders pallets for a shipment, PalleTech will deliver them to any drop-off location, and then pick them up at any requested pickup location after the shipment is complete. If the shipments follow a continuous, closed loop sequence (like Kaneka's), then PalleTech allows the customer to keep the same pallets and re-use them, paying a fee each time a pallet is used for a shipment.

The cost (quoted on 12/13/2016) is **$7-10 per pallet, per shipment:**

- Any shipping distance
- 90 day window per shipment, then cost is prorated

In Kaneka's case, the yearly cost of using this service will depend on the total number of totes (162) and the frequency with which they complete the shipping cycle. Since the shipping route for the totes takes 2-3 months to complete, I will assume that all 162 totes complete the shipping cycle once every 2-3 months. In this case, the yearly cost to Kaneka is calculated as follows:

(12 months) / (2-3 month shipping cycle) = **4-6 cycles per year**
(162 pallets) * (4-6 cycles per year) * ($7-10) = **$4,536 – $9,720 per year**

Although this is a high yearly cost, it is likely insignificant compared to the value of the assets being transported. Also, trying the service involves absolutely no risk. Kaneka is not responsible for any pallet maintenance, and will always receive charged, functional pallets on demand. Since Kaneka will be charged on a per-pallet, per-trip basis, there is no up-front investment required, and the service can be cancelled anytime.

Contact:

I spoke directly with Richard Linkesch, the founder of PalleTech, whose contact information is below. I explained Kaneka's shipping needs to him over the phone, and all of the information about PalleTech presented in this report comes directly from him. Please feel free to contact Richard and reference the phone conversation that I had with him on 12/13/2016.

Richard Linkesch
Founder, PalleTech
415-279-3726

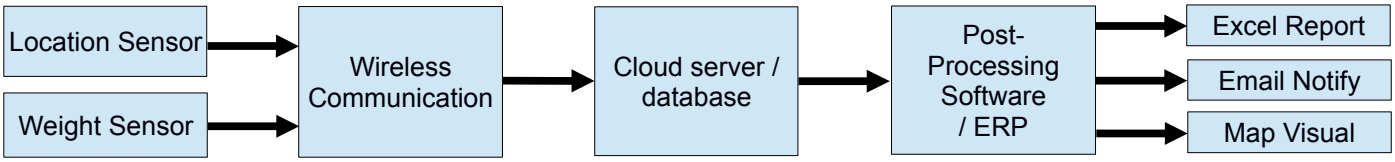
Alternative Solutions

If an asset tracking service like PalleTech is chosen, then almost all aspects of the problem are taken care of automatically (data collection, communication, cloud server, analytics, map visualization, device installation and maintenance, etc.). PalleTech is currently the only asset tracking solution available in the U.S. which offers geographical location tracking in the form of a pallet. There is another company called iGPS, located in Orlando, FL, which also makes “smart” pallets, however not all of their pallets have GPS sensors in them, and they do not release the location data to their customers. iGPS’s pallets are mainly used as an alternative to wooden pallets for cost savings and environmental impact reasons. The GPS tracking in these pallets is only used by iGPS internally to recover lost or stolen pallets that they lend out to customers. The pallets do however contain barcodes and RFID tags which could be used to track them on the customer side, but this would require touch points where the pallets would have to be scanned by an RFID scanner. Some additional information about iGPS is included at the end of this report.

If a “smart” pallet solution winds up not being viable, the only other option is to treat the location and weight tracking as two different problems, as explained in the following sections.

Workflow:

Regardless of the solution chosen, it will have to follow the workflow shown below in order to meet all of the functional requirements.

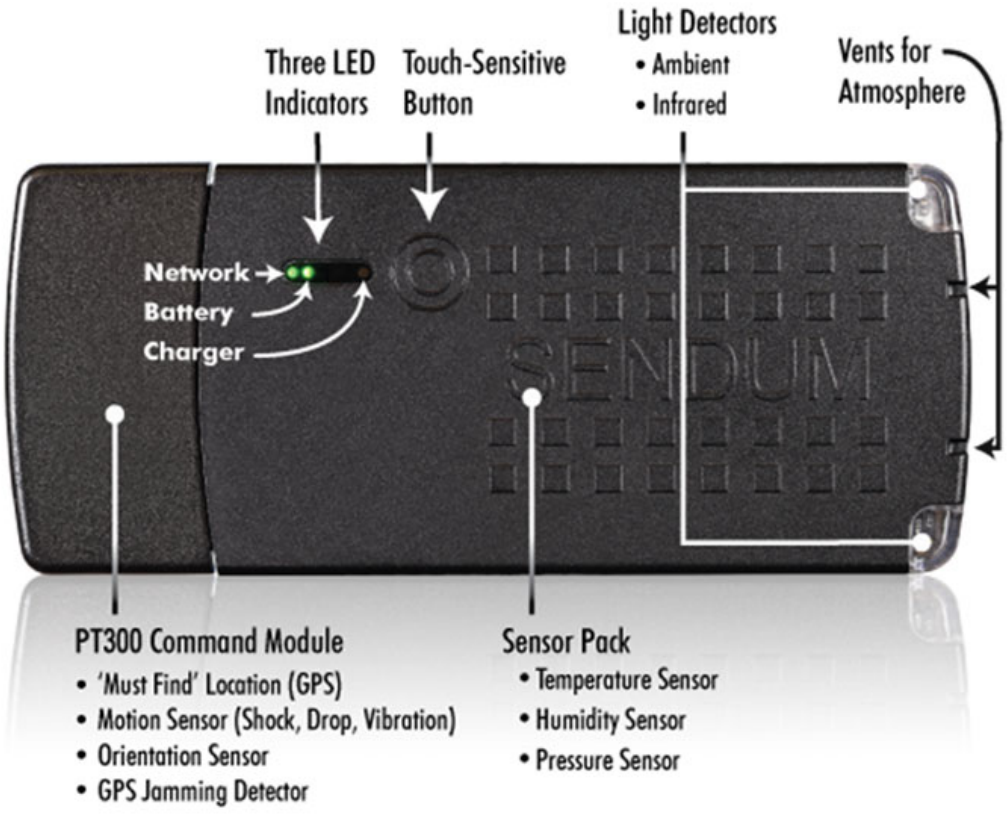


Two sensors will be required to measure the geographic location and weight of each tote. That information will then need to be sent to a centralized location (cloud server) where Kaneka employees can review it. A custom post-processing software will likely need to be written to convert the raw sensor data into usable information in the form that Kaneka employees will be expecting it to be in. This custom software tool will also be required in order to generate the Excel report, as well as display the tote locations on a map. The sensor data will also be integrated into Kaneka’s SAP ERP system either directly, or indirectly via the post-processing tool. The post-processing tool can be set up to run autonomously.

Location Sensor:

SENDUM

The two technologies that should be employed for location measurement are GPS and cellular tower triangulation. Both are readily available in off-the-shelf products. If a standalone location tracking device is required, I recommend using the **Sendum PT300**.



Courtesy Sendum - http://sendum.com/pt300-package-tracker/

Features:

- The PT300 is capable of measuring the following:
  - Geographical location
  - Motion
  - Shock
  - Orientation
  - Battery level
  - GPS jamming detection
  - Temperature (advanced model only)
  - Relative humidity (advanced model only)
  - Barometric pressure (advanced model only)
  - Light (advanced model only)
- "Findum" cloud software included, and contains a **map interface** as well as several other analytical tools
- Findum API available for sending data **directly to ERP system**
- Real-time notifications triggered by sensor data
- Small, lightweight, portable, and self-powered

Advantages	Disadvantages
• All-in-one solution for location tracking • Ready to use immediately • Data sent to cloud via cellular network, accessible anywhere, even indoors • Long battery life (21 days if polled twice per min, significantly longer life in “Deep Sleep Mode”) • No additional transmitter module required, standalone product	• No weight measurement • Unsure of cost at this time • Unsure of pricing model or who is responsible for maintenance / replacement / recharging • Probably not weatherproof, likely requires additional protective box

The Sendum PT300 seems to be an excellent solution if only location tracking is required. The cost is unclear at this time since Sendum has not yet replied to me with a quote. This device could be mounted to a tote or to the pallet which the tote sits on. In order to protect the PT300 from damage during cleaning and transportation, it would be wise to place it within a weatherproof box, and then mount the box to the tote or pallet.

Courtesy Pelican - http://www.pelican.com/ca/en/product/watertight-protector-hard-cases/micro-case-series/standard/1030/

Each of these Pelican cases costs about **$15-20,** so this would add a cost of around **$3,000** up-front for 162 totes. This case is shown as an example of what would be required. I am not necessarily recommending this particular case.

Weight Sensor:

Measuring the weight of the totes is the most difficult aspect of this problem, and there are several techniques that can potentially be used. Some of these include:

- Direct weight measurement by placing a load cell under the tote
- Measure fluid pressure at the bottom of the tote
- Measure the deflection of the walls of the tote as it is filled with fluid, perhaps using strain gauges
- Measure the volume of fluid in the tote (or fluid level) and back-calculate the weight based on the known density of the fluid
- Measure the acoustic signature / pitch / resonant frequency of the tote. The nature of vibration of the tote will change depending on the amount of fluid in it, just like a glass will change pitch when tapped with a spoon depending on the amount of water in it.

There are advantages and disadvantages to each of these techniques. Kaneka's approach should be to prioritize a solution that is off-the-shelf and ready to go. I have experience working at a company that manufactures sensors, and I can attest to the fact that designing a custom sensor will require extensive development work and cost, not to mention the lack of customer service and technical support that are included with off-the-shelf products. Keeping this in mind, I recommend that Kaneka avoids designing a custom weight sensor for this application, but rather seeks out a supplier who can provide a proven solution immediately.

Although the PalleTech solution currently lacks the capability to take weight measurements, the company is planning to add the functionality in 2017. Once this functionality is added, the PalleTech system will be a single, all-encompassing solution. However, if Kaneka cannot afford to wait until PalleTech adds weight measurement functionality, my recommendation would be to take a pressure measurement on the inside of the tote, at the bottom. A wireless bluetooth pressure sensor can be used **in conjunction with PalleTech** by using the PalleTech transmitter as a gateway to transmit the pressure sensor's data to the cloud.

The benefits of a pressure measurement are as follows:

- Fluid pressure is directly proportional to fluid weight
- Pressure increases linearly with depth below a fluid surface
- Wireless pressure sensors are currently available off-the-shelf
- Pressure sensor would probably be easy to implement on the tote

The CirrusSense TDWLB Wireless Bluetooth Pressure Transducer is an example of a self-powered, bluetooth pressure sensor that is currently available off-the-shelf.

Courtesy Transducers Direct - http://www.transducersdirect.com/wireless-bluetooth-pressure-transducers-tdwlb

Features:

- Durable construction
- Wireless
- Self powered
- 1% accuracy

Advantages	Disadvantages
• Ready to use immediately • Long battery life (12-18 months)	• Additional central transmitter required to upload data to cloud (not included) • Post-processing of data is necessary to convert pressure to weight • High cost ($189 each, $30,618 total) • Kaneka owns sensor and is responsible for maintenance • Small pressure port (around 1/8 inch) might not accept thick adhesive well, sensor might require modification • Pressure to weight conversion would likely be different for red, green, and blue adhesives, especially if their densities vary significantly

Theory of Operation:

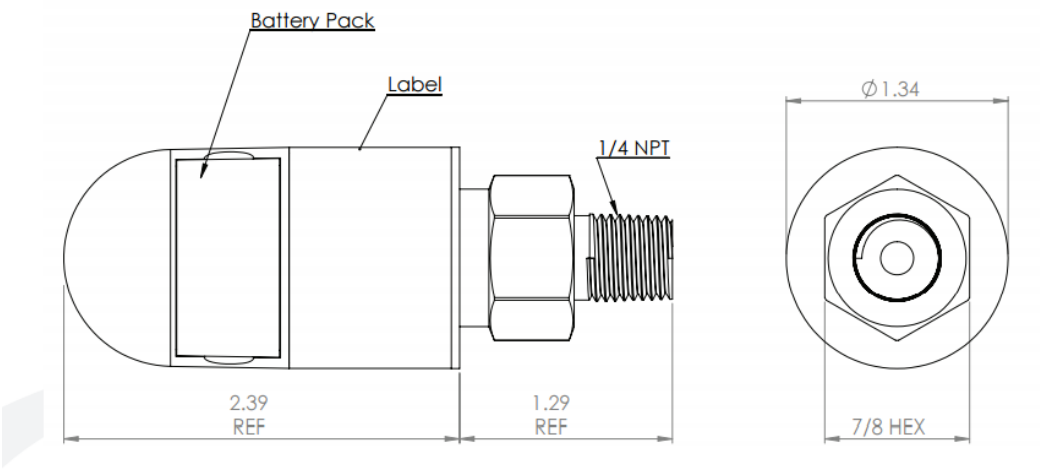
In a vessel containing fluid, the pressure at a depth “h” below the fluid surface is calculated using the following equation:

$$P = \rho g h$$

where:

P = fluid pressure at depth “h” below surface
ρ = fluid density
g = gravitational acceleration constant (9.81m/s^2)
h = depth below fluid surface

The biggest challenge and risk with measuring pressure in this application will be the fluid itself. The pressure sensor might have trouble measuring an extremely viscous fluid, mainly because such sensors are usually designed with very narrow “ports” through which the fluid is able to enter the sensor.



Courtesy Transducers Direct - http://www.transducersdirect.com/HeleoCart/Data/SoftGoodPreview/TDWLB_(9.16).pdf

A very thick fluid might not be able to flow through the narrow port and into the sensor. This could be fixed by modifying the sensors' ports, or simply working with the sensor supplier to select a sensor with a sufficiently large port hole.

Another consideration is the classification of the adhesive material, aside from simply the viscosity. Pressure measurements are easily taken on Newtonian fluids, but non-Newtonian fluids, or Bingham Plastics, will probably not allow for an accurate fluid measurement. An example of a non-Newtonian fluid is toothpaste, which is essentially a solid until pressure is applied to it, at which time it is able to "flow" like a fluid. However, it's flow properties are different from Newtonian fluids. Such a material would likely violate the assumptions of the pressure/depth equation presented above (**P = ρgh**), and so even if the sensor was able to measure the pressure of a non-Newtonian fluid, the measurement would not necessarily be proportional to the weight of the fluid in the tote.

Since the fluid being transported is also an adhesive, it would destroy the pressure sensor if it were to dry and harden over time. I cannot comment on whether or not this would happen without knowing more about the adhesive, for example whether it cures on its own at room temperature or requires heat or external chemical components to cure. The method used to clean the totes should also be considered so as not to destroy the sensor.

Assuming these concerns are resolved, the pressure sensor would be fairly simple to implement out-of-the-box. Assuming there is some kind of valve and tap on the bottom of the tote where Kaneka and the customer currently pump the adhesive in and out, the pipe that is there could be spliced upstream of the valve and a fitting could be retrofitted to accept the pressure sensor.

Courtesy Transducers Direct - http://www.transducersdirect.com/pressure-transducers

The sensor will have a standard NPT thread on its port, so this and/or other fittings can be used to create a threaded inlet where the sensor can simply be screwed in. Over the life of the tote, the sensor would be very easy to replace; it would simply need to be unscrewed and another one could be screwed in to replace it.

Measuring pressure will also require data processing because the pressure values will have to be converted to weight values so that Kaneka's employees can make sense of them. This might require some debugging as well. The first time the system is used, a test tote will likely have to be set up on a reference scale to compare the weight measurements taken by the pressure sensor to those taken by the reference scale. If they don't match, the post-processing algorithm which converts the pressure data to weight data would have to be tweaked (easily) to make them match. This would essentially be "calibrating" the pressure sensor to take accurate weight measurements in these specific totes.

Another downside of measuring pressure is that the conversion to fluid weight would likely be different for the red, blue, and green versions of the adhesive. As a result, the pressure sensors would have to be adjusted, or "calibrated," differently on each of the 3 colored totes.

Cost:

The bluetooth pressure sensors can be purchased from **Transducers Direct for $189 each.** There will also be additional costs for pipe fittings and technician time to retro-fit each tote with a port where the pressure sensor can plug in. I will add an arbitrary 30% cost increase to the estimate to cover these additional costs. There will also be some maintenance required, including replacing sensors that break or lose battery power (perhaps 20 sensors replaced per year, conservatively). In addition, software development time will be required to integrate the sensor's bluetooth output data into the PalleTech transmitter.

Sensors	($189) * (162 totes) = $30,618 one-time cost
Other parts/labor	0.3 * $30,618 = $9,185.40
Bluetooth integration	(~$30 per hour) * (80 hours) = $2,400
Maintenance	($180) * 20 = $3,780 per year ongoing
Total:	**$42,203.40 one-time cost** **$3,780 per year ongoing**

This option is significantly more expensive than using PalleTech as a standalone solution.

Wireless Communication:

There are potentially two stages of wireless communication required in this application, depending on the solution chosen. The main one allows data from the tote (sensors) to be sent to the cloud and stored in a database. The best choice of communication technology for this data transfer is **cellular.** There are other options, including WiFi, satellite, etc., but cellular is the only one which offers reception indoors and nearly anywhere on the globe (wherever there are cellular towers nearby).

As an added benefit, a cellular enabled device can determine its approximate location based on the towers it connects to, so there is no need for GPS, which will have limited reception inside a truck or train-car where the totes will be spending most of their time. GPS technology relies on there being clear lines-of-sight between the device and the satellites because the signal has trouble passing through many common materials, including building walls and truck/train walls. The products mentioned above use a combination of GPS positioning and cellular tower triangulation to calculate location.

The other stage of wireless communication that will be necessary (depending on which solution is chosen) is the short-range relaying of the weight sensor signal to a transmitter which is capable of cellular communication. The most readily available protocol for this short range communication is BLE (bluetooth low energy). Almost all of the products mentioned in this report employ bluetooth in some form. This makes it possible, for example, for the PalleTech product to be combined with a separate bluetooth pressure sensor and used as a gateway to transfer both location and pressure data to the cloud in one shot. This could be used as a short-term solution while PalleTech works on implementing weight measurements directly into their pallets.

Cloud Server / Database:

If an off-the-shelf solution like PalleTech is chosen, the data from their system will automatically be uploaded to the cloud and they will provide a software tool for viewing it (including a **map interface**). I spoke to their founder and he said the data can also be easily routed into other cloud servers of choice, or ERP systems. In the end, the PalleTech system could be easily configured to send all of the data directly to Kaneka's SAP system where employees could access it and generate automatic reports. If PalleTech is not chosen, Kaneka will have to hire a software developer to set up a server and write code that will receive, store, and process incoming data from the totes.

Post-Processing Software:

Regardless of the solution that is chosen, some kind of post-processing software tool will have to be written. The primary reason for this is that Kaneka employees want the location data to state the "stage" in the shipping process rather than the raw latitude and longitude coordinates. In order to do this, there will have to be a software function which analyzes latitude and longitude values from the location sensor and determines whether the tote is "Michigan Empty," "Michigan Filled," "On Truck Michigan," "On Train Southbound," etc. The software will also have to pair the location data with the weight data to be able to distinguish an empty tote from a full one at different stages in the shipping process.

Finally, as previously mentioned, if pressure is used to measure the fluid weight, then it will need to be converted to weight units with a simple calculation. Depending on the solution chosen, and where the data winds up getting stored, this data processing could either be implemented by writing a custom piece of server software, or perhaps using Excel cell formulas in the final spreadsheet that is reported out. Kaneka's ERP system, or PalleTech's software portal, might also have the capability to perform simple data manipulations, but I am uncertain of that.

If Kaneka winds up using a custom cloud server and post-processing software, then the Google Maps API or the R statistical package (both free) can easily be used to plot the locations of the totes on a map. Any web developer should be able to easily implement one of these two map visualizations.

Conclusion

The most promising solution for tracking Kaneka's totes as they are shipped around North America is **PalleTech,** a "smart" pallet rental company which tracks pallet locations in real time and delivers that data to the customer through a web or mobile application. Although the pallets are not currently capable of measuring weight on their own, they provide the flexibility to add additional third party sensors and send the data from those sensors, as well as the location data from the pallet, to the cloud via a common PalleTech transmitter. I recommend that Kaneka pilots the PalleTech system as-is and considers waiting until the end of 2017 for PalleTech to add weight sensing functionality to their pallets, as they have planned. The PalleTech solution will cost Kaneka **$4,536 – $9,720 per year,** making it the most cost-effective solution available as a standalone product, with almost no modifications or add-ons required.

If weight sensing capability is required in a shorter timeframe, I recommend using a bluetooth pressure sensor in conjunction with PalleTech until PalleTech implements weight sensing technology on the pallets themselves. Implementing the pressure sensors will add an additional one-time cost of around **$42,203,** plus ongoing maintenance costs of around **$3,780 per year.** The feasibility of using pressure sensors will have to be evaluated based on the material properties of the adhesives being transported.

If neither the PalleTech nor the wireless pressure sensor solutions pan out, the **Sendum PT300** can be used immediately for tracking location only. The durability of this device to adverse conditions as well as its cost are both unknown at this time. If the device is not weatherproof on its own, it might require a weatherproof enclosure to keep it protected when it is mounted to the tote. Implementing a

readily-available, consumer-level enclosure from Pelican could cost around **$3,000** for 162 totes, but such an enclosure would have to be further evaluated for durability and ease of mounting to the tote.

Regardless of which solution is chosen, an additional cost will be incurred developing a custom software tool that will present the location and weight data in an Excel spreadsheet as required for Kaneka employees. This could be implemented at a relatively low one-time cost, perhaps around **$2,000 – $5,000** for hiring a software developer. Integrating the data into Kaneka's ERP system could add some cost, but would probably be covered by a technical support agreement that Kaneka already has with the company that provides the ERP system, as well as Kaneka's internal IT resources.

Additional Resources and Ideas

Geoforce GT0 and GT1 Devices:

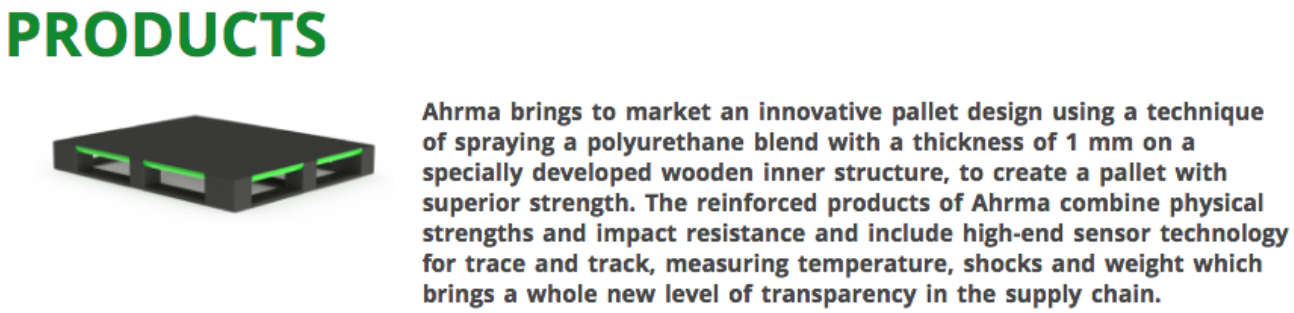
Courtesy Geoforce - https://www.geoforce.com/tracking-devices/gt1-global-asset-tracker

- Readily-available solution for location tracking in the field
- Similar to Sendum PT300
- Intended for tracking outdoor field equipment
- Excellent battery life (3-5 years)
- $149 each at volume of 170 units
- Flexible platform for integrating into Kaneka's other systems and sensors
- Will not work for Kaneka because it uses satellite communication to transfer data to the cloud. Satellite signals will not travel through truck and train walls very well, and those places are where the totes will spend most of their time. They also transmit at a designated time each day, so they will not necessarily transmit as soon as they are given a clear line-of-sight to a satellite.
- Besides the GPS shortcomings, this looks like an excellent product and the company is ready and willing to work with Kaneka. I spoke to a sales representative on the phone who's contact info is below.

  Henry Rosen, Geoforce
  Sales Representative
  214-499-5004

Ahrma Pooling:

Ahrma Pooling is a logistics IT company in the Netherlands that makes a smart shipping pallet which is a great candidate for a drop-in solution. Below is a blurb from their website:

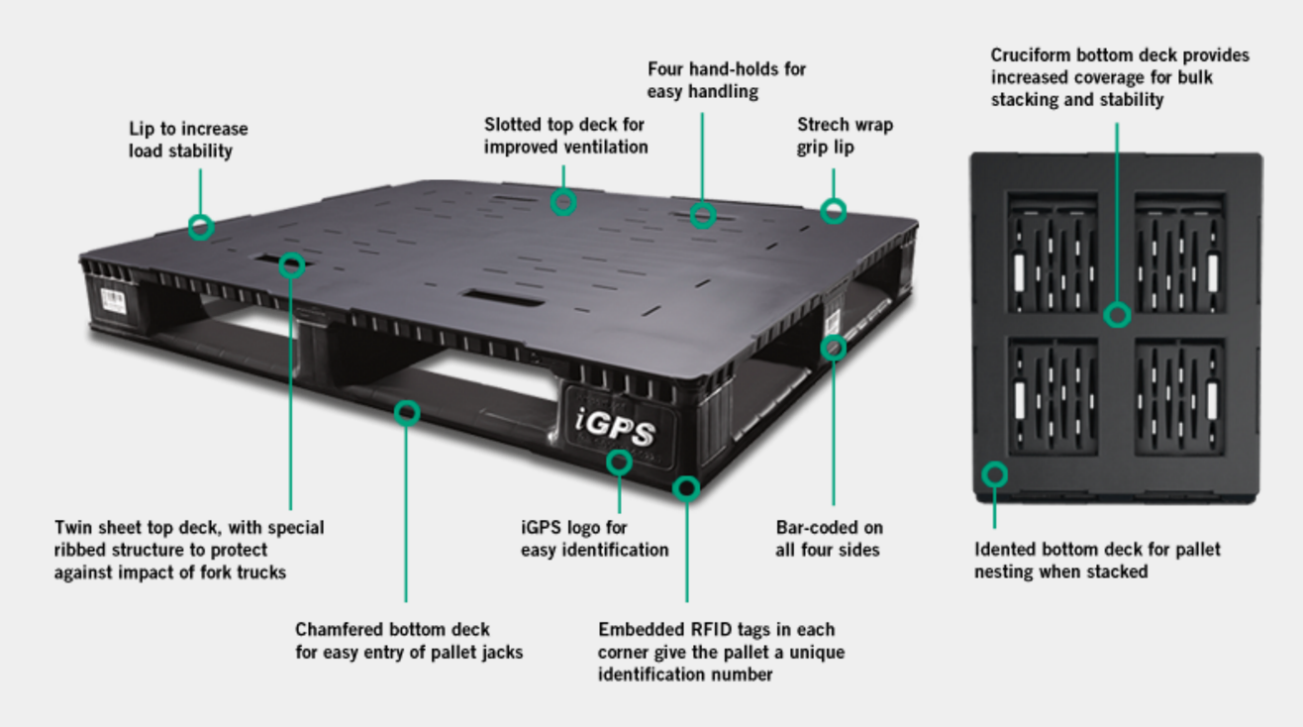


Courtesy Ahrma Pooling – http://ahrmapooling.com/#/products.

Ahrma's pallet is the only one currently on the market that measures both geographical location and weight in a single, standalone device. This product would be a perfect solution for Kaneka, however it is not for sale. The company does shipping pooling, and all shipments are routed through their own warehouses. They use the pallets to track their own shipments, but they do not sell them as a product or a service to other companies. I highly recommend contacting them and negotiating a deal to purchase some anyway.

IGPS:

iGPS is an American company, located in Florida, which offers a similar product to Ahrma's.



Courtesy iGPS - http://www.igps.net/platform-spec-sheet.aspx

iGPS' platform is light and durable, but it lacks the location tracking capabilities or services that Kaneka requires. Like Ahrma, iGPS uses the location tracking capabilities of the pallets for their own internal use, mainly to recover lost or stolen pallets. They sell this product with the simple promise that it is better than a wooden pallet, being lighter, more durable, and lasting longer. The customer has no access to the "smart" tracking capabilities of the device. Even if they did, not all of the pallets have GPS sensors built in, so there is no guarantee that the pallets delivered to a customer would have the capability. The pallet does contain RFID tags that the customer is able to use, but the tags require scanners to be nearby to read them (i.e. "touch points"), which is not realistic for Kaneka's shipping route. Otherwise, the service functions similarly to PalleTech, where the pallets are delivered in one place and picked up in another. iGPS charges a $0.08 per-day rental fee per pallet, so for 162 pallets the yearly cost would be similar to or slightly less than PalleTech, at **$4,730.40,** but with far less functionality and value for Kaneka's application.

My Contact Information:

I enjoyed working on this project, and I hope I have provided Kaneka with some valuable information to help track the totes. Please feel free to reach out to me for additional information or questions as I was limited by time to the amount of information that I could include in this report. Thanks.

Andrew Schneer
Mechanical Engineer