Final Report

AUSTRALIAN MEAT PROCESSOR CORPORATION

Industry 4.0 - Evaluation of Digital Twins – Stage 1

Digital Twins – Remote Collaboration - Virtual Reality – Worker Validation and Training – Multi-User Virtual Worlds

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1.0 Executive Summary

This project was conceived as an opportunity to evaluate the power and utility of a Digital Twin of a meat processing facility. JBS Brooklynn was identified as an ideal partner, with an openness to allow our team full access to their facilities, both during weekend shutdown and during production mid-week. To-date, JBS hadn't invested in a Digital Twin and was interested in just how it could assist them to identify efficiencies and bottom-line impacts, and the AMPC of course wanted to identify how any benefits could be extended and scaled across the meat processing industry.

One utility that was initially identified, was around onboarding and validation of potential new worker hires. Currently, new workers train for up to 3 weeks before they really get amongst the production floor and understand the full parameters of day-to-day work in a meat production facility. And some workers are given that costly time and training, but when they are finally at with the coalface of production, decide it just isn't for them, and quit. So one of the purposes for a Digital Twin, that was initially identified, was to very quickly allow trainees to be immersed in production through the use of Virtual Reality, and make that decision then and there. This would save time and money and would also generally increase the motivation of staff – who are only surrounded by those who are prepared to work and who will likely stay with the business longer and become more valuable with attained skills, knowledge, and experience.

It is worth noting that Covid 19 played a significant role in the delayed completion of this project, because of the general restrictions in VIC, and with travel from NSW, and shutdowns at JBS Brooklyn.

2.0 Introduction

The purpose of this research was to identify just how far Digital Twin technologies had progressed, and how it could potentially assist the meat processing industry. A Digital Twin is a digital representation of a real-world entity or system. The implementation of a digital twin is an encapsulated software object or model that mirrors a unique physical object, process, organization, person, or other abstraction. Data from multiple digital twins can be aggregated for a composite view across several real-world entities, such as a power plant or a city, and their related processes. https://www.gartner.com/en/information-technology/glossary/digital-twin .

The digital twin market will cross the chasm in 2026 to reach $183 billion in revenue by 2031, with composite digital twins presenting the largest opportunity. Product leaders must build ecosystems and libraries of prebuilt function and vertical market templates to drive competitiveness. https://www.gartner.com/en/documents/4011590#:~:text=Summary,market%20templates%20to%20drive%20competitiveness.

Hence, with Digital Twins making so much progress across so many other industries, all stakeholders working on this research were intrigued to know how this could be useful for a industry with such a large human-work element right now, and without the extreme automation of some other food production industries that are not dealing with products a complex as meat, and therefore have a much lower price point for entry into heavy automation.

The scope of this research was to initially just create a significant amount of 3D, of several production lines at JBS Brooklyn:

1) Boning Room 2 in the lamb production line
2) Boning Room 3 in the lamb production line
3) The Offal Room

We then intended to create a small, demonstrative experience of a worker being able to stand in a 3D static version of a room and see what that environment is like. At the end, we intended to deliver the 3D models and a VR experience.

There had previously been some discussion of Digital Twins at JBS, and curiosity around it. There are a few definitions of Digital Twin going around, with some being based on a sort of functional, data-connected animation, and others based on something that is more of a WYSIWYG (what-you-see-is-what-you-get) 3D model that is a highly accurate simulation of the real world. We intended to head towards the latter, so that the 3D could be used for many other purposes.

Image 1.0 – Simple Digital Twin of a Power Plant produced by General Electric and Visionaze
https://www.automationworld.com/factory/plant-maintenance/article/22314727/ge-digital-adds-3d-digital-twin-accelerators-to-asset-performance-management

Image 1.1 – hi-fidelity Digital Twin of the French city of Pau, created by Aerometrex from 100,000+ photographs from helicopter, drone, and at street level. Created to preserve the history of the city but also for future construction and infrastructure projects. https://aerometrex.com.au/resources/projects/pau/

To-date, there has been very little done with Digital Twins in the Meat Processing industry. Schneider Electric and the Danish Technological Institute produced s simple, data-driven Digital Twin of a theoretical, highly-automated meat production-line to help promote the benefits of full automation (https://xcelgo.com/danish-technological-institute-develops-true-digital-twin-in-experior/). But while JBS has implemented a significant (and successful) robotics system for carcass quartering, and Schneider's Digital Twin may assist if making a business case for more automation, the balance of cost and practicality currently favour a large human-factor on the production line, so this sort of model may not have maximum utility for some time yet.

This project was very much designed to be investigatory, with no actionable outcomes that could be commercialised at an early stage. That said (and as you will read further in the report), we accidentally stumbled across very useful and deployable tools that could add value to the industry very quickly.

3.0 Project Objectives

The official single-minded objective of this research was: 'to ascertain the benefits (or not) of the application of a Digital Twin to red meat processing facilities'. Ultimately though, there were a number of wish-list items that were raised by JBS stakeholders, across two areas: Operations, Planning and Training.

3.1 Operations

Those who are involved in day-to-day management and maintenance of JBS Brooklyn had several hopes for the Digital Twin. These were based around a greater ability to diagnose and address specific issues as follows:

3.1.1 Maintenance issues

It was hoped that the Digital Twin could better allow maintenance engineers to isolate and address acute and longer-term issues across the production equipment. Being able to share spatial knowledge about exactly where an issue is occurring, anyone involved in the conversation can get on the same page very quickly, *wherever they are in the world*.

3.1.2 Production Flow

The idea of having an animated twin that is running at the speed of production was raised – so that chokepoints could be better identified, even for equipment investment purposes. While that was outside the scope of this initial project, it was identified that this project would likely provide the foundations required to do this.

3.2 Planning

It was hoped that the Digital Twin would allow JBS decision makers to visit the production-floor very quickly and easily (virtually) and be able to have constructive conversations about optimisation. We also theorised whether we could virtually 'test out' equipment in the space.

3.3 Training

Because the basis of immersive training is to put trainees into full 3D simulation environments in VR, it was hoped that a Digital Twin would again be foundational for creating the scenarios that trainees, and those being re-trained or upskilled, could have a sense of reality – while not needing to be in that real-world place (and potentially in the way of real production).

4.0 Methodology

At first, we intended to approach this project by doing LIDAR (light-detection-and-ranging) 3D point cloud scans of the 3x rooms. At the same time, we intended to take thousands of photos by camera and by drone, of the facilities. This was so that we could combine the point cloud with the photos in photogrammetry software, to create our 3D models.

As we did our research on the very latest advancements in photogrammetry and consulted full-time experts, it became clear to us that we would struggle enormously with quality of the light in the room, combined with the reflectivity of steel surfaces everywhere. And we suspected that, in practice, we may have similar issues with the LIDAR scanning as the infra-red laser dots bounce around the 'hall of mirrors.

Nevertheless, we travelled to Melbourne, to JBS Brooklyn, with a Leica BLK360 - which is a LIDAR scanner which is designed for smaller spaces. The first space we worked on was Boning Room 3. This room has an incredible amount of equipment and conveyers and machines that are tightly packed into the space. The room was in 'weekend mode' when we went to scan – which meant the cutting boards had been put away, everything had been hosed down, screens and some other equipment was covered in green plastic and tables were dismantled from the production line.

We very quickly learned it would be a very big scanning task to ensure we got into every nook and cranny of the room. All-up, the scan took almost 11 hours, to gather spatial data from almost 80 locations.

Image 2.0 – Virtual Method on-site at JBS Brooklyn with the LIDAR scanner, moving it from point to point around the facility.

Image 2.1 – Original outputs from the LIDAR: a colourized pointcloud. .

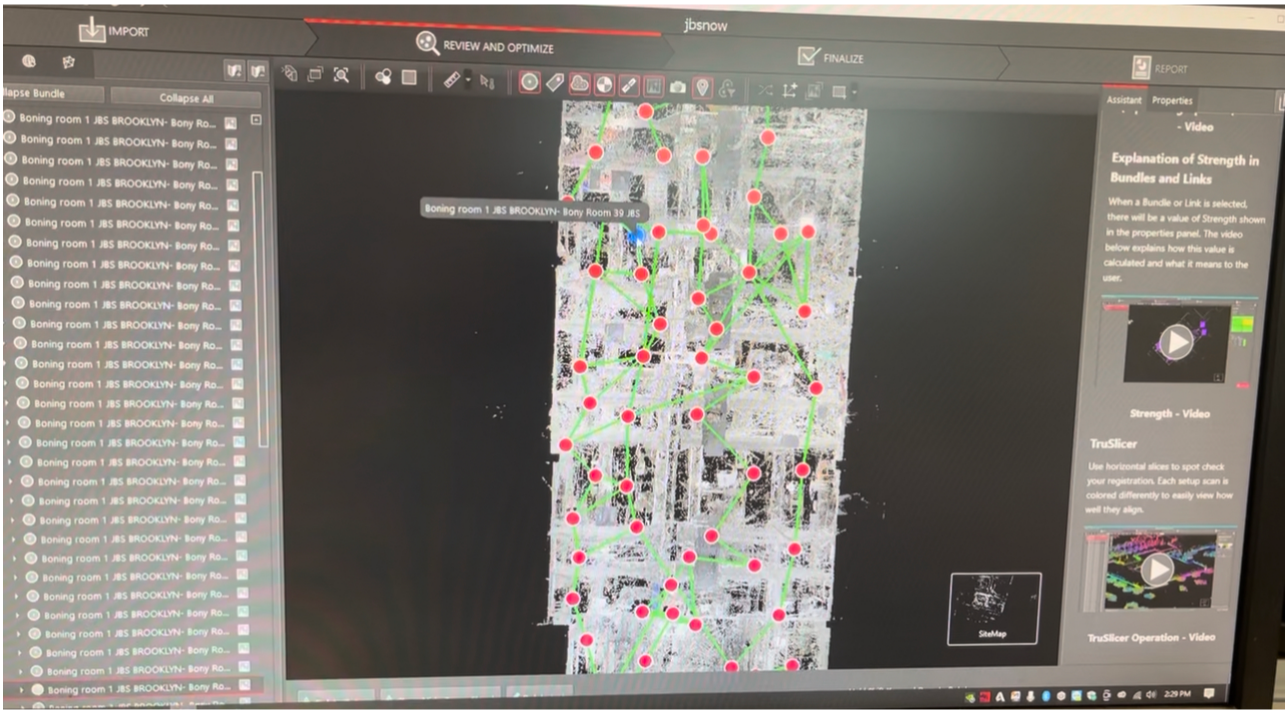

Image 2.2 – All the pointclouds callibrate and mesh with each other to form the whole-room model.

We then scanned the Offal room and subsequently ran out of time to move onto Boning Room 3, as we had scanned for ~18 hours and ran into the end of the weekend, the end of the shutdown period. So, we travelled back to Sydney with the data.

We then processed the data through Leica's Cyclone Register Software, so that all the scans registered to each other very precisely. While conducting our own extensive research into available tools, we had come across an early-stage start-up called Prevu3D. They had developed software that would ingest point cloud data and use a combination of software and AI to cloud-process point clouds into mesh and textures – which is exactly what we needed so that the scan could become a workable 3D model.

Doing a test initially, we were disappointed with the results. As suspected, the reflective metal surfaces in the Boning Room 3 made the laser data quite scattered and this caused the model to be of a poorer quality than we hoped. That said, when we viewed the room in panorama mode, we could still do things like make highly accurate measurements point-to-point – but the visual quality was very high. Even in full 3D mode however, and despite the imperfections, the model was very useful for measuring and annotating with notes (which we could allocate to someone as a task).

We could also 3D 'box and remove' any item from the space and show the potential for replacing it with 3D models of new equipment – to test it out in-situ before purchase. We were also able to invite another remote stakeholder to join us in the space and walk around freely whereby we could see in the model where they were standing and looking. This was available on PC and in VR. The emerging technology that enables such incredibly complex 3D models to stream into PC browsers is called NVIDIA Omniverse.

Image 2.3 – The Offal Room as a meshed 3D output, struggling with the reflections. But still able to be accurately measured.

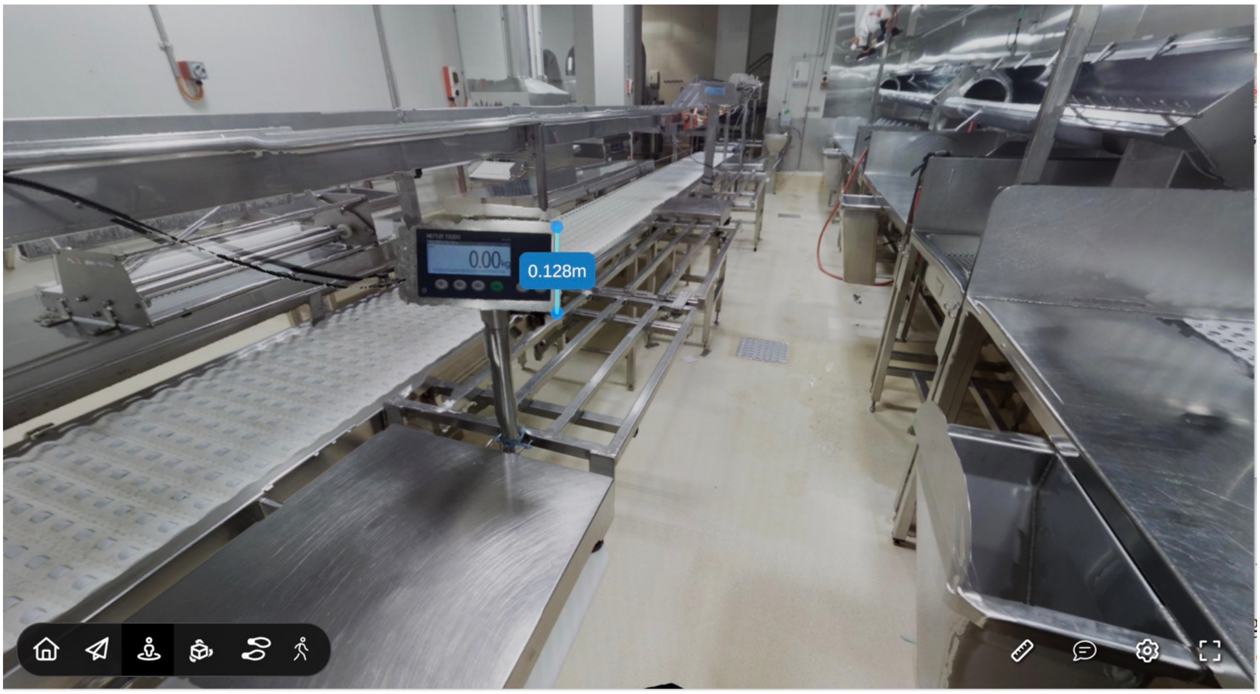

Image 2.4 – The Offal Room as panoramas, but still supported by the useful spatial data from the mesh version. But still able to be accurately measured, as can be seen in this image.

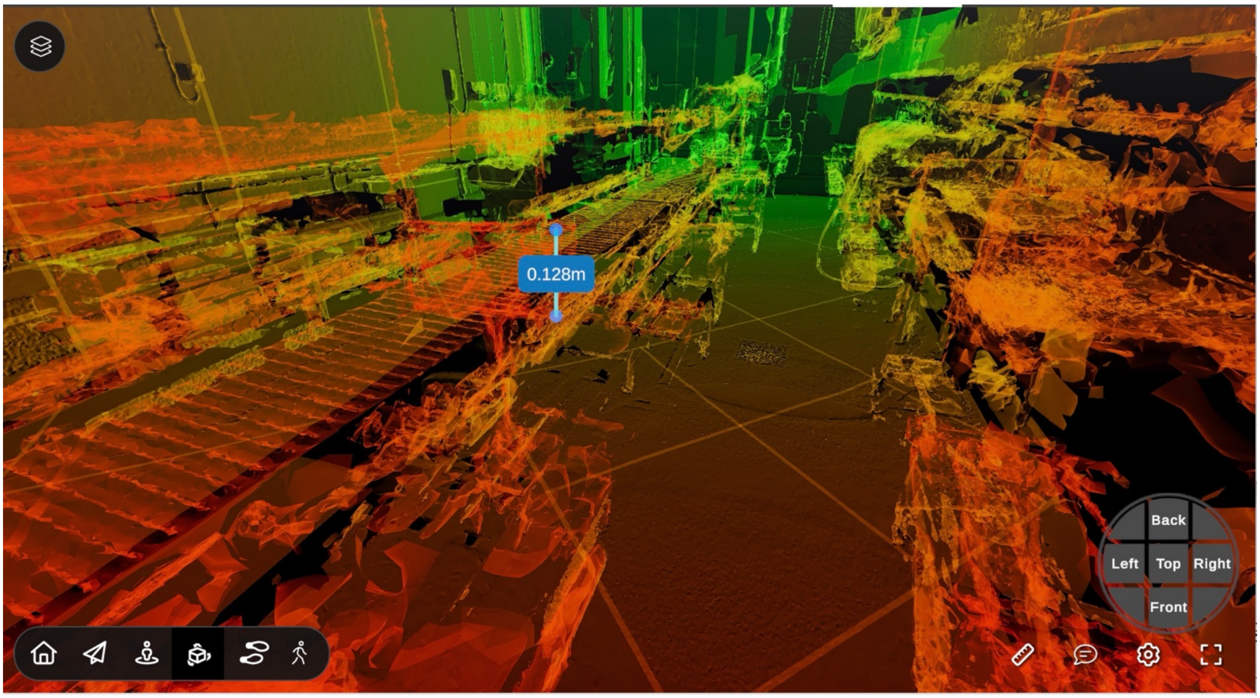

Image 2.5 – Depth spectral mode, which is especially useful for top-down views, so that any inclines and declines in the floor can be identified easily, which is important for food production manufacturing as the pooling of liquid is an important hygiene consideration.

It was at this point we realised that just doing a static model of this environment wasn't going to allow us to achieve one of our biggest goals: to allow trainees to immerse themselves into the reality of meat production. The immersive experience would be devoid of people, of energy, of meat and 'production-action'. We subsequently suggested to the AMPC and JBS that we omit the scanning of Boning Room 1 and instead, go back to JBS Brooklyn during full production, and use our very hi-fidelity Insta 360 Pro One-Inch camera to 360 video-capture a number of locations across Boning Room 3 and the Offal Room so that we could connect it to the Virtual Reality static environment. The shoot was a success, except there are some 360 video shots that contain (what looks like) flashing lights because the 360 video-camera was running at 30fps and the eco-lighting in the facility must also have a frequency of around 30 pulses per second.

We then downloaded the model of Boning Room 3 from Prevu3D and our modellers set about using it as a template to model-out a certain cutting area in the room. We then dropped the model into the UNITY Game Engine and created procedural shaders to make the belts animate within the experience. Finally, we connected the 360 video panoramas so that they could be interacted-with and watched.

We uploaded this all to our secure cloud where it combined with our interaction and avatar systems so that anyone, anywhere can join the scene and interact + talk with anyone else who is there. The beauty of the system is that this can be done in:

1) a browser on a PC, or
2) in a tethered headset like VIVE Pro or Varjo, or
3) in an untethered headset like Meta Quest Pro, VIVE Focus 3 or Lenovo Thinkreality VRX.

Our virtual reality cloud environment and software is ISO27001 certified and can even be run on-premises, for high-security needs. In an enterprise environment, in Australia especially, where *cybersecurity* has recently become an extremely high priority, having that level of security is an imperative. Our platform, used in this project, is securely used by Nestle food manufacturing. AstraZeneca, Pfizer, Shell and BP worldwide for that very reason.

The secure, virtual cloud used in this project also has turnkey integrations with SAP SuccessFactors and Workday LMS systems (and can connect with others quite easily), so that any skills-based training can track up-to 30 data points per user, per-second, and all that data and any accreditations can be federated directly into worker employment records, credentials and plant-access permissions.

5.0 Project Outcomes

While we executed on the ***core*** requirements of this research, the project was true to the nature of agile research and development, in that it opened-up a lot of possibilities as well, that were unexpected. As far as Digital Twins are concerned, we learned that the capture of food production environments is particularly challenging. The highly reflective metal surfaces make LIDAR scanning and photogrammetry extraordinarily difficult. There is a process whereby special sprays can be applied to metallic surfaces that 'mattify' them and prevent the bouncing of light, and that spray (which appears white at first) fades away after around 2 hours. But it isn't food safe, unfortunately.

That said, the Digital Twin that we were able to produce has a number very powerful, immediate benefits and utilities otherwise, including:

1) The ability to navigate through the space in photo-real panorama-mode, while collaborating with remote viewers. This is an ideal way to showcase partners the facility, but also 3rd party consultants and vendors who might want to view and advise on new equipment, better processes etc – without getting in the way of production.
2) The ability to accurately measure-up anything within the twin, precise point to point, without having to get on the production-floor with a tape measure. The measurements can be very advanced and 3D volumetric, even.
3) Despite the meshed 3D spatial twin being quite rough due to the reflectivity, equipment and infrastructure can be clip-boxed and 'removed' from the plant floor, and a 3D model of a new piece of equipment (from a 3rd party vendor for example) can be uploaded and placed in-situ, whereby it's suitability and logistical compatibility can be visually and spatially checked.
4) Any item within the twin can be annotated as a task or point of follow-up and allocated to a particular worker. That worker can then access the twin, via the browser, on a ruggedised tablet in the plant and, by clicking on the task, will be visually and spatially 'zoomed-to' so the worker or his/her supervisor can understand exactly where to go, and can complete the work quickly and efficiently. The completion of tasks can then be marked-off and viewed by other stakeholders. This is an extraordinarily powerful tool, which spatially anchors and records current + historical asset data which very quickly visualises what is required to be done physically, in that space.
5) The 3D model can be downloaded across a wide range of file formats, and then used by 3D modellers, such as those on the Virtual Method team, to create well-surfaced models and animations of any part of the facility, as we did with the trimming station in Boning Room 3. And *that* model can form the spatially accurate 3D basis of any VR training, learning and development requirement so that the simulation of performing tasks is done in the true-to-life facility.

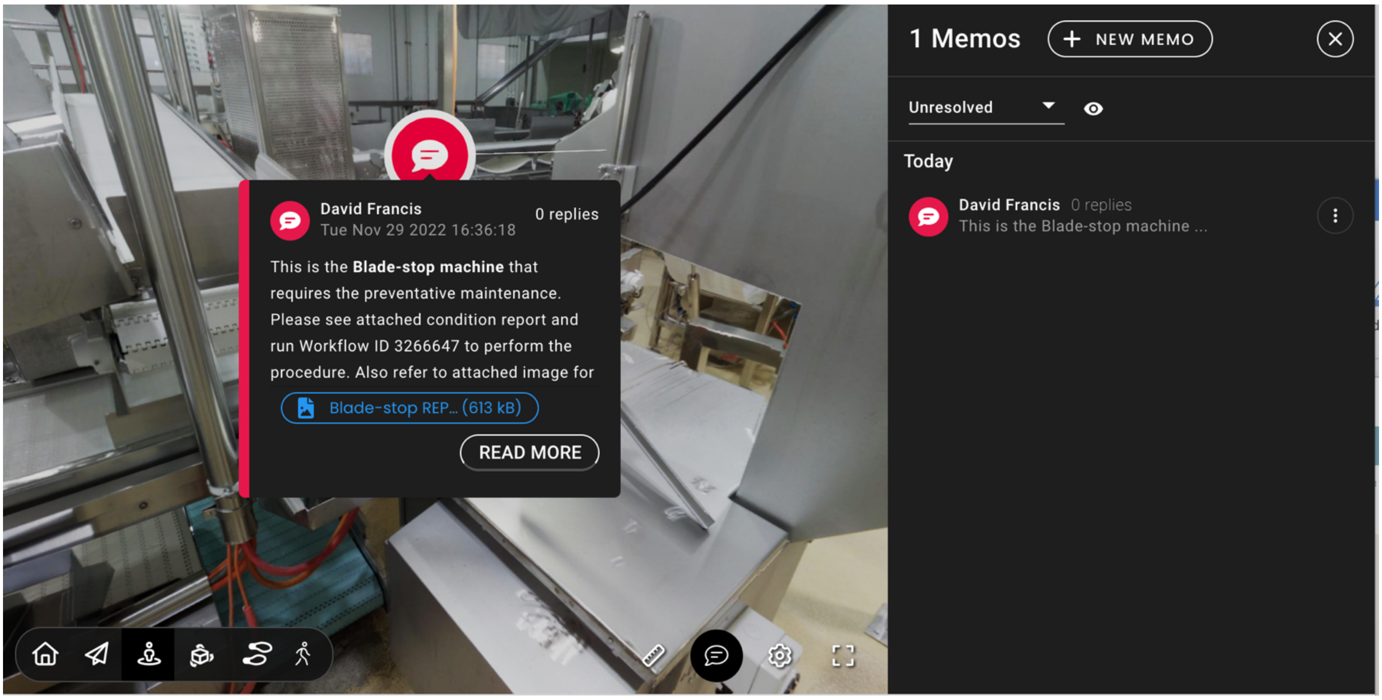

Image 3.0 – Annotating tasks that are required, spatially. This means that a worker can be colour-coded (eg – "all light blue tasks are mine") and they have a spatial map of exactly which piece of equipment they need to fix/assess. No confusion, no need to 'be shown where'.

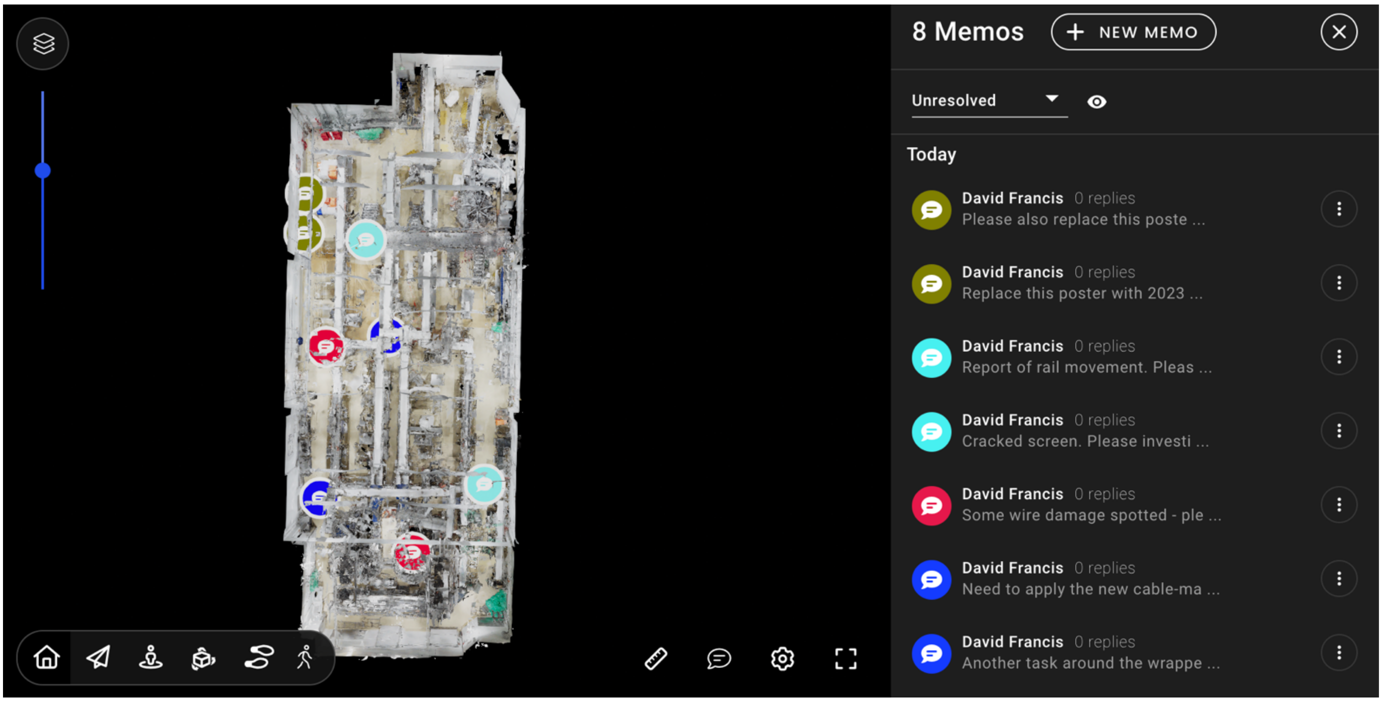

Image 3.1 – At a snapshot, any facility stakeholder can see what is and isn't unresolved. And they can see that on the Digital Twin of the room or the entire facility, from anywhere in the world.

The Digital Twin production process pipeline we have developed is also fairly straightforward for meat processing facility managers to do themselves. The minimum requirements would be a Leica BLK360 G2 (much faster than the G1 we used), the Leica-Hexagon software on a tablet, and access to the Prevu3D cloud to be able to upload the point-clouds and convert them into Digital Twins. That autonomy of production is a huge breakthrough in the Digital

Twin industry, where previously a Digital Twin could cost well into 6 figures for just one space, even without travel costs included for the capture-professionals.

Further to the Digital Twin automation outcomes, the pivot we made to high quality 360 videos has also paid dividends. In trials, we have discovered just how extraordinarily useful it is to be able to 'virtually jump-inside' a multi-user VR experience and co-inhabit (with other remote stakeholders) a 360 video panorama that is showing live production. It is not practical or at all common for meat processing industry senior stakeholders to stand and observe production, right at the coalface of where it is happening. There is only enough space for one person to stand in some of these production environments, let alone co-inhabit the space with another person and discuss optimisation of processes and workflows.

But in our multi-user VR environment, we can do exactly that. We can now have several virtual users, who could be completely remote to each other (even in different countries) 'stand' in the live production environment. Not only does this give these stakeholders a perspective they have never seen before, but they can discuss face-to-face and gesture to points-of-interest inside the 360 videos, to greatly increase time-to-mutual-understanding and identify better ways of doing things.

Again, high quality 360 videography has now become extremely accessible and affordable through devices like the Insta360 Pro. And while the uploading and set-up of these 360's in a multi-user VR environment isn't yet as do-it-yourself a function as the Digital Twin creation is, it would be a nominal cost to do-so through an XR specialist like Virtual Method.

Image 3.2 – 360 panorama of the Offal Room. Every perspective is covered and, when wrapped 'around' the User, in a VR headset, gives a very strong sense of presence – and of every aspect of the pace, energy and action in that part of the production process.

For the Australian Meat Processing industry, the outcomes of this project represent an affordable and powerful way for any facility to establish all the infrastructure that is needed to create immediate value and ROI from the speed and succinctness of communication, the consequent massive reduction in time-to-mutual-understanding from issues with current production, all the way through to planning and optimisation of the production line. Every aspect of potential platform evolution has been thought-of, with 10-15 year foresight, including:

1) Scalability + Affordability - through empowered DIY Digital Twin creation.

2) Multiple Utilities – the raw point-cloud can be used across many other utilities into the future – including Microsoft Mesh and Azure Spatial anchors which will allow wayfinding and AR-anchored content in the next generation of AR glasses.
3) Anti-redundancy – as the Twin can be hosted both in the Prevu3D cloud (NVIDIA Omniverse-powered) – but also in UNITY3D (or you could export and download a 3D format and store in your own, secure cloud)
4) Accessibility – our virtual environment works across a very wide range of devices and interfaces, from PC screens to tablets/phones and a broad selection of tethered and untethered VR head-mounted-displays, giving industry stakeholders a wide range of choice.
5) Inclusion – our multi-user VR environment allows stakeholders from every aspect of meat process value-creation to join-together and collaborate in highly contextual virtual worlds, from wherever they are geolocated on the planet, and have round about 5MB/s (up/down) of connectivity or more.
6) Cybersecurity – our system is globally certified and used by organisations involved in operations-critical ‘sovereign security’ around the world, and has all the time, diligence and certifications invested in it to ensure this is the case.
7) Training – the Digital Twin creation, multi-user collaboration enablement and turnkey deep LMS integration represents and exceeds the minimum requirement for a truly scalable world-class VR onboarding and Training program.

Image 3.3 – inside the real-time 3D modelled area of Boning Room 3, the two virtual collaborators (one in Sydney whose eyes you are seeing through, and one in Brisbane in pink) are having a discussion and decide to view the trimming station 360 video.

Image 3.4 – the VR collaborators discuss what they are seeing and what the workers are doing. They are able to point-to various points of interest to clarify their questions and answers.

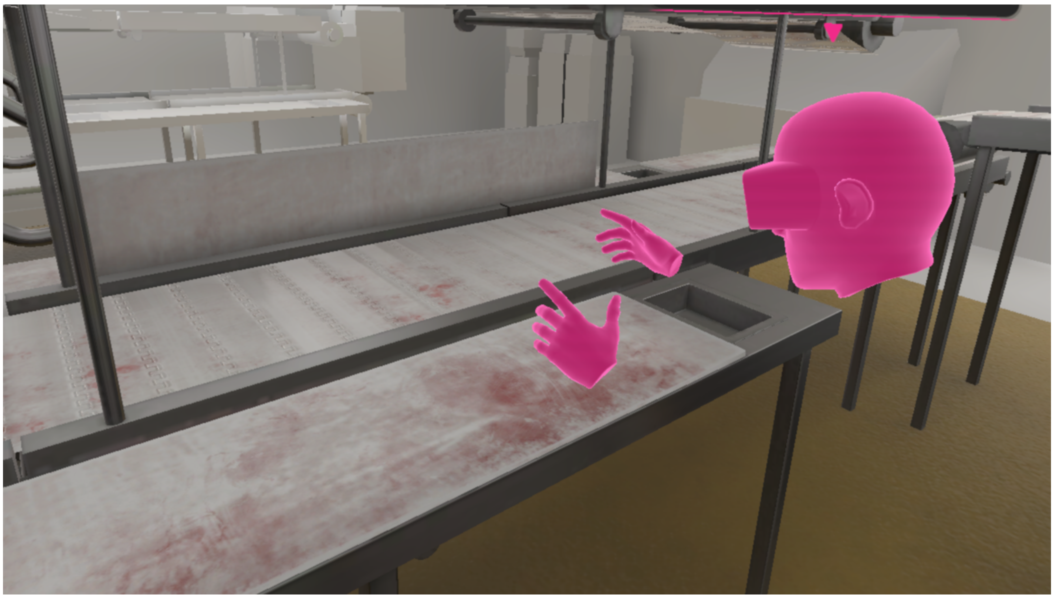

Image 3.5 – back inside the real-time 3D modelled version of what they just saw and discussed in the 360 video, the two virtual collaborators can now move freely around the space, pick up virtual knives and kinetically-train alongside that seasoned professional.

Image 3.6 – alternatively, the two virtual collaborators can visit any part of the production process, most especially as an onboarding process to qualify what work a potential hire is most suited-to (or not), to help prevent a post-training worker attrition rate.

The outcomes of this project can be commercialised and scaled quickly, so that all industry stakeholders can achieve the same results as JBS Brooklyn, quickly and affordably.

6.0 Discussion

The results of this work highlight just how important a Digital Twin will be, for the Australian Meat Processing industry to reach the performance benchmarks required for maximum output, profitability, and global competitiveness in the years ahead. The impracticality of getting onto the production floor amongst workers at full-pace, knives and hooks and the Q-Fever inoculation requirements, and just the tyranny of distance for anyone to get to a facility like JBS Brooklyn (or other facilities around Australia in remote regional areas) means that a Digital Twin is an ideal way for anyone to get eyes-on a facility when-needed (eg immediately), and from anywhere.

Undoubtedly, the capture process would be even more ideal for other parts of the plant that aren't high-reflectivity food processing environments, and this should potentially be investigated.

The requirement of speed is also an important training element that hasn't been investigated, to-date. Anyone can cut-up a piece of meat correctly, given time. But *can they do it at the very fast speed required to keep up with the conveyer systems and other workers*? When we started to run the conveyer 3D-shader in our VR onboarding experience, which makes the conveyer run at the pace of the real world, we realised that the static VR experience could easily be extended to the virtual cutting of meat at-pace, and could be gamified against a points system – for accuracy *AND* speed.

This project also highlighted the power of remote virtual collaboration and raised the possibility of creating a 'Meat-a-verse': a virtual, online world whereby meat processor stakeholders could meet face-to-face virtually and be exposed to presentations, supplier briefings, industry updates and meat processing best-practice + advances. And as per the virtual cloud system used in this project, the 'Meat-a-verse' could be experienced from anywhere and through a desktop computer or through VR headwear (ideally – for maximum immersion).

Another area of discussion is the possibilities of attaching real-time sensors, SCADA, HMI and other systems-data to the Digital Twin. So that the real-time progress of the plant floor can be identified and visualised in-context, and that data will further help to quickly identify any chokepoints and inefficiencies in the real-time context of the production floor.

The AMPC could also potentially become a member of the global Digital Twin Consortium (https://www.digitaltwinconsortium.org/) and act on behalf of the industry, working alongside the world's leading manufacturers who are also employing Digital Twin technologies successfully.

7.0 Conclusions / Recommendations

As a Phase 2 of this project, our recommendations are in three parts:

1) That we should advance our current VR multi-user build a little further so that it can become a deployable onboarding module that gets used in the real-world onboarding of new employees. This can be a template for any and every meat processing facility in the country (or world, really). We could then experiment with extending this experience into soft skills training required to work in any facility.
2) That we use the Digital Twin data to model-out and animate Boning Room 3. Further to that, we would seek to API into the sensors and human-machine-interfaces of that production floor so that the status of the production line can be reviewed in real-time. We would run (animate) the virtual equipment at real-time, and could also gamify our hero cutting station to give workers a sense of the pace required, through fun and play.
3) We use the point cloud we have of JBS to incorporate Microsoft's new Mesh and Azure Spatial Mapping technology to create a virtual to real world AR collaborative experience.

What we have discovered in this process is how powerful a Digital Twin is, to share and succeed knowledge within the meat processing industry. But the inclusion of 360 videos + training elements + a proper, cybersecure LMS integrated cloud has begun to establish a global industry-first actual pipeline. A process, a recipe for digital transformation of a meat processing business. One leads to the other: so that a Digital Twin is the foundation of spatially anchored predictive maintenance but is also the foundation for proper VR simulations of every and any part of the production line. And the spatial data also opens up huge possibilities for spatial wayfinding + augmented reality being used on the production floor.

8.0 Bibliography

'GE Digital Amps Up Asset Performance Management'	Image 1.0 (Page 4)	Image courtesy of https://www.automationworld.com/factory/plant-maintenance/article/22314727/ge-digital-adds-3d-digital-twin-accelerators-to-asset-performance-management

Digital Twin of the French city of Pau	Image 1.1 (Page 5)	Image courtesy of: https://aerometrex.com.au/resources/projects/pau/