Industry 4.0 in New Zealand dairy industry

Fariz Aziz, Shaqir Samsudin, Neeraj Nambiar, Uthman Aziz, Eric Li and Ray Y. Zhong*

Department of Mechanical Engineering,
University of Auckland, New Zealand
Email: maba@aucklanduni.ac.nz
Email: asam843@aucklanduni.ac.nz
Email: nnee565@aucklanduni.ac.nz
Email: uaba395@aucklanduni.ac.nz
Email: lli867@aucklanduni.ac.nz
Email: r.zhong@auckland.ac.nz
*Corresponding author

Abstract: New Zealand may be has the largest dairy industries in the world due to natural resources suitable for cows. It is facing new opportunities because a new generation of industry termed as Industry 4.0 is coming. Facing the new technologies, how traditional dairy industry in New Zealand could seize the golden opportunities in the context of Industry 4.0 to upgrade and transform? This paper analyses the current status of New Zealand dairy industry and gives some investigation results. Some significant insights and lessons from this study could be used for guiding dairy industry which is contemplating the implementation of Industry 4.0 enabled solutions.

Keywords: Industry 4.0; New Zealand; dairy industry; technology management.

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Biographical notes: Fariz Aziz is an undergraduate student in The Department of Mechanical Engineering, University of Auckland, New Zealand. His research interests include internet of things (IoT) and additive manufacturing such as 3D printing.

Shaqir Samsudin is an undergraduate student in The Department of Mechanical Engineering, University of Auckland, New Zealand. His research interests include internet of things (IoT) applications and 3D printing.

Neeraj Nambiar is a current student from the Faculty of Engineering, University of Auckland, New Zealand having just completed his Masters in Engineering Management degree. He has completed his Bachelors in Electronics and Telecommunications Engineering from University of Mumbai, India. Having completed his Bachelors, he worked for a reputed IT company in India for three years. This is his first foray into the research field and hopefully many more to come.

Uthman Aziz is a fourth-year Mechanical Engineering student at University of Auckland, New Zealand. His research interests include internet of things (IoT)-enabled manufacturing and additive manufacturing such as 3D printing. His final year research project entitled 'Fused deposition modelling and life cycle testing of a rehabilitation knee brace' won the award from Fisher and Paykel Healthcare New Zealand. He is a student member of the Engineering New Zealand.

Eric Li is a student completing the Master degree of Engineering Management, University of Auckland, New Zealand. He gained his Bachelors and Masters in Electronics Engineering from the Hubei University of Technology (China) and Shenzhen University (China), respectively. He is specialised in electronics engineering industry with over 12 years' working experiences. He has worked for several multinational companies, including Samsung, Corning, Synnex and was put in charge of international projects in various parts of the world. He is also a professional member of Engineering New Zealand and Engineering Australia.

Ray Y. Zhong is a Lecturer in The Department of Mechanical Engineering, University of Auckland, New Zealand. He gained his MPhil and PhD in Signal and Information Processing and Industrial and Manufacturing Systems Engineering from the Guangdong University of Technology (China) and The University of Hong Kong (Hong Kong), respectively. His research interests include internet of things (IoT)-enabled manufacturing, big data in manufacturing and SCM and data-driven APS. He has published over 100 papers in international journals and conferences. In addition, he has participated in a set of projects sponsored by the National R&D Department, HK ITF and HKU. He is a member of CIRP RA, ASME (USA), HKIE (HK), IET (UK), IEEE (USA) and LSCM HK.

1 Introduction

New Zealand as one of the biggest countries which have diary sector as the leading industry has contributed enormously by providing dairy products to the whole world for many decades. It was reported that diary industry contributed to 26% of the total value which is obtained from merchandise exports in 2015–2016 (New Zealand Dairy Statistics, 2015–2016). There are five million numbers of cows for milking with 8,315 farm owners/operators in this country. Dairy industry creates 49,110 jobs with the total 12.2 billion New Zealand dollars in the past year. Recently, New Zealand government proposed some policies to upgrade this industry by using cutting-edge technologies.

Industry 4.0 as our next generation of industry uses various advanced technologies such as cyber-physical system (CPS), Internet of Things (IoT), and cloud computing for automation and intelligence manufacturing (Jazdi, 2014; Lee et al., 2015; Ivanov et al., 2016; Trappey et al., 2017b; Zhong et al., 2017e; Zhong and Ge, 2018). Industry 4.0 was firstly proposed in German and later on, it has been attract world-wide attentions. In 2012, GE introduced the concept of the Industrial IoT (IIoT), suggesting that intelligent machines, advanced analytics, and connected people are the key elements of future manufacturing in order to enable smarter decision-making by humans and machines

(Kagermann et al., 2013; Brettel et al., 2014; Rauch et al., 2017). In 2015, Japan commenced its Industrial Value Chain Initiative (IVI), which corresponds to Germany's Industry 4.0 initiative, in order to connect businesses via the internet (Ivanov et al., 2016; Didactic, 2017). In 2015, China's State Council unveiled a 10-year plan to upgrade the nation's manufacturing capacity to allow it to catch up with production powerhouses such as Germany and the USA (Liu and Zhong, 2017; Lu, 2017a). It could be observed that manufacturing, transportation, and service industry have taken some actions (Lee et al., 2014; Lu, 2017b). However, dairy industry as one of an important sector is still in a primary stage of using Industry 4.0 enabled solutions.

As Industry 4.0 promises a huge potential that could improve the operations of dairy industry (Douphrate et al., 2013; Li et al., 2018). This paper takes New Zealand dairy industry for example to examine the opportunities of using some cutting-edge technologies in Industry 4.0 to upgrade and transform traditional industry into a smart future. The reasons for the upgrading and transforming are summarised as follows. Firstly, the increasing demands for dairy products are hard to meet by using traditional production systems which are usually with high labour costs and low efficiency. Such production systems are not sufficient to ensure the quality of dairy products such as freshness and safety since they are perishable items. Secondly, dairy products are becoming more and more diversified. Due to the large number of diversity, typical manual-based working systems are not capable of catching up the customised requirements from different end-users. Finally, dairy farming is being held to account for the environmental impacts, for example the effect of dairying on water quality. Thus, sustainable dairy industry should be achieved by considering using more advanced technologies.

The rest of this paper is organised as follows. Section 2 gives an overall of dairy industry in New Zealand and the methodologies used in this research. Section 3 reports on the Industry 4.0 in New Zealand. Opportunities for New Zealand dairy industry is illustrated in Section 4 with some applications. Some cases and discussions are given in Section 5. Section 6 concludes this paper by giving some insights.

2 Dairy industry in New Zealand

2.1 Current status

New Zealand's biggest export revenue mainly comes from the dairy industry with a yearly production of 21.3 million litres of cow's milk as shown in Figure 1. This makes New Zealand as the 8th largest milk producer in the world. Many resources are used for dairy industry in New Zealand with nearly 1.8 million hectares of land and $13.2 billion of revenue generated in 2017. This shows that the expansion of dairy industry in New Zealand has a significant contribution to the nation's gross domestic product (GDP). New Zealand is also expected to grow to a massive population of 5.51 million by 2025, therefore it is essential to develop the dairy industry to meet the increasing demands (DairyNZ, 2015). It is evident that the dairy industry in New Zealand can be upgraded to a completely new level, thus, making New Zealand as the point of reference for other countries in respect to dairy industry. With the facts in the background, it is necessary to gain a clear picture of the limitations and problems of the current status and how Industry 4.0 can contribute towards minimising the problems.

Figure 1 Statistics of New Zealand dairy industry in 2015 (see online version for colours)

2.2 Methodology

To identify the current limitations and problems in the dairy industry, site-visit sessions had been conducted to a few companies. These sessions helped create a clear picture about the process of the companies and their readiness to adapt Industry 4.0. For further understanding, a set of questionnaires were given to the company to gauge the company's intuitiveness and willingness for Industry 4.0. Based on the above methodology, the limitations and problems of Industry 3.0 have been identified. Table 1 shows the differences between Industry 3.0 and 4.0 in the dairy industry.

Table 1 Differences between Industry 3.0 and 4.0 in dairy industry

Industry / *Tech evolution*	*3.0*	*4.0*
Sensors	Isolated and different standards	Smarter and more flexible for connection
Connectivity	Connected using wired or wireless communication standards	Intelligent networking from single sensors to the cloud-enabled system
Data usage	Data used for visualisation and statistics report	Data used for pattern recognition, machine deep learning, etc
System integration	Isolated systems with limited information sharing	Seamlessly integrated with real-time data communication
Security	Traditional firewalls, encryption methods, and authority control	Advanced cybersecurity methodology, vigilant and resilient approaches
Automation	Robots-assistant production system	Smart robotics for autonomous manufacturing
Decision-making	Data-driven decision-making models	AI-based intelligent models using big data analytics

2.3 Limitations and problems

New Zealand has a mature dairy industry and a majority of the Industry 3.0 technologies are being implemented in all dairy-related businesses. While Industry 3.0 has provided a solid foundation, the effect of expensive costs in pastures, insufficient and inexperienced labour, the demand for sustainable growth and fierce competition from other businesses have brought further problems, which cannot be solved efficiently with the current Industry 3.0 techniques. The following limitations have been identified with the current Industry 3.0 technology in the dairy industry.

- Resource limitations: Rising cost of labour and pastures constraint the scale expansion, thus the dairy industry is facing challenges of maximum production with limited resource, based on current technologies.
- Information transparency: The data from different sensors and machines cannot be automatically linked together to work out an optimal solution.
- System limitations: Using the current IT systems, dairy firms lack flexibility to quickly adjust each process to meet changeable demand, i.e., they can only make business decisions through manually changing the mould assembly or formula of materials.

As a leading industry in New Zealand, most dairy companies rely on experienced labours to manage farms and produce dairy products. The following problems have been identified with respect to the dairy industry.

- *Inconsistent quality of milk:* The cost of labours has increased consistently for many years in New Zealand, and hence dairy farm owners must spend more money on hiring employees. This is magnified by the fact that many farmers are expanding to pastures which are outside of the main urban areas, which amplifies the labour shortage effect. Hence, the quality of milk is inconsistent as finding skilled people to work has become increasingly difficult.
- *Monitoring Cows:* Taking care of dairy cows is a 24-hour job. Farmers always need to have some employees to look after hundreds of cows at night, in case of urgent issues such as heavy rains etc. Proactive herd health management is critical for keeping the dairy cows safe for producing high quality products.
- *Managing health and productivity of cows:* The health and productivity of cows are the most important elements to ensure the quality and quantity of diary products. Keeping tracking of the health of the cows can be a time-consuming job as it is inefficient especially with larger herd sizes through manual-based mechanism. Combined with effect of decreasing labour pools, farmers often find this a tedious job and hence may neglect it at the consequence of the health of the cows.
- *Issue identification in time:* When an issue occurs, most farmers take a long time to identify the root cause and find a solution to fix it, due to the limited usage of cutting-edge technologies. The identification is usually based on some data analytical tools which are not sufficient in current systems.

- *Inefficient usage of lands:* Overgrazing, overuse of fertilisers and non-irrigation has become critical issues in the dairy industry. Farmers need to meet the increasing demands from the market, while their lands are not used efficiently as they may not have the systems and technologies to manage.
- *Unwillingness and budget control:* Some emerging technologies are shunned by farmers for several reasons. Firstly, they see it as too much of a hassle to implement these new technologies as it is hard to justify the benefits. Also, they may not be as technologically minded and may find learning new systems a hassle and not worth the time or money.

3 Industry 4.0 in New Zealand

The implementation of Industry 4.0 technology has recently enhanced the development of various industries in New Zealand. This section briefly explains the Industry 4.0-based technologies applied from major industrial sectors in New Zealand.

3.1 Manufacturing

An Industry 4.0-outfitted manufacturing factory will have better drive productivity that can keep the costs down and ensure quality, consistency and a competent business model across the entire manufacturing processes. The use of Industry 4.0 technology will ensure the quality of product which is not outmoded and the manufacturing facilities are flexible so that business can remain stronger ability in the competitive market (Almada-Lobo, 2016; Wang et al., 2016).

In 2017, New Zealand IoT Alliance has been established to conduct a thorough research on the impact of Industry 4.0 technology especially in the manufacturing industry. Full automation or robotic in the manufacturing assembly line together with the emerging of IoT technology will navigate the future manufacturing factory into a new dynamic phase with outstanding efficiency performance in its production line (Zhong et al., 2013, Wallis et al., 2014). The research suggests that by implementing the Industry 4.0 technologies, manufacturers who export pieces of machinery equipment around the world can monitor the status of the equipment regardless of the locations because advanced sensors are deployed and real-time status data could be sent to the cloud-based system. This enables the manufacturer to conduct remote performance management and preventative maintenance on the component.

An example of Industry 4.0 vision-oriented company is Fisher & Paykel Appliances Subsidiary Production Machinery Ltd (PML), who has developed an enterprise solution that networks manufacturing processes. PML has been focusing on developing fully automated and special-purpose production line machinery for a range of industries (Lu et al., 2017; Zhong et al., 2017c). PML strategic model is to have strong alignment with the digital transformation of manufacturing technologies and the Internet Plus visions by integrating the internet with the traditional manufacturing industries. Among the early products of PML towards the Industry 4.0 direction is to develop a manufacturing operations management software product called as COSMOline (Zhong et al., 2015). The

software will be able to unlock the full potential of production machinery through the act of collecting, analysing and acting on the quality, efficiency, maintenance and environmental data that are being generated by the equipment itself (Callaghan Innovation, n.d.).

Another company is the Pilz New Zealand, a member of the SmartFactory KL demonstration and research platform. Pilz is in collaboration with other partners of SmartFactory KL on a production line that demonstrates the practical application and equipment that are Industry 4.0 enabled. For instance, a storage module developed by Pilz is used to provide intelligent, automated storage for the workpiece carriers. In this advanced automated storage, the control systems, drive technology, various sensors, visualisation systems and network infrastructure components and operation are fully integrated and interconnected in the context of Industry 4.0 (Pilz, n.d.).

3.2 Information and communication technology

Although Industry 4.0 begins with advanced manufacturing, the supporting technologies mainly come from information and communication technology (ICT) sector. The development of ICT will not only be in the education and work opportunities, but as well as the real-time data development that will operate and manage broadband ICT in diary industry (Paredes, 2016).

In New Zealand, the development of ICT with strategic alignment in the Industry 4.0 vision can be seen through Huawei's recent efforts. In 2016, Huawei hosted the first IoT Innovation Forum in New Zealand to bring together a range of academics and industry people to share their visions in a better connecting world. The shift to an ultra-broadband future and next generation mobile networks will provide the framework for widespread interconnectivity of devices that range from simple and small devices to large and complex ones (Zhong et al., 2016a). Huawei also believes that by 2025, there will be more than 100 billion connections worldwide, known as the IoT.

IoT will give many disruptions but also plenty of opportunities over the next five years, therefore a few strategic plans were made by Huawei to cope with the development of Industry 4.0. Huawei plans to build a cloud data centre in New Zealand as part of the five-year ICT infrastructure investment into the nation that is worth up to NZD 400 million (Moss, 2017). Huawei's plan also includes building an innovation lab at the Victoria University of Wellington and in Christchurch with the purpose of looking at 5G, big data and the IoT (Mcbeth, 2017).

Other than Huawei, in 2016, SIGFOX, (the world's leading provider of dedicated communications service for the IoT) and Thinxtra (an IoT network operator) established a partnership to extend the SIGFOX IoT network to Australia and New Zealand. In addition, Thinxtra also receives major support from a publicly traded New Zealand company, Rakon Limited, which designs and manufactures advanced frequency control and timing solutions for telecommunications, space and defence applications.

SIGFOX networks are designed and built specifically for implementing the IoT technology. As a staunch wireless network, SIGFOX network provides the ICT infrastructure to connect millions of low-energy industrial objects such as smart water metres, environmental sensors and tracking applications. These applications need low-cost connectivity and emit small amounts of data, which will be managed through the ICT framework connections of SIGFOX networks (Kordia, 2016).

3.3 Construction

The construction sector incorporates Industry 4.0 technologies to improve its productivity to meet an ever-increasing demand (Zhong et al., 2017a). Law Hawk provides document automation service to various industries including the construction industry. They help customers to sort and manage their own documents in a way their customers want. This company has prepared over five versions of 3,910 construction contracts which cover design and build, civil work measure and value, consultancy agreements, civil works lump sum etc. (Ministry of Business, Innovation and Employment, 2013). This is an example of adopting the big data concept, which involves processing a huge amount of data to derive useful outcomes (Zhong et al., 2016b).

There has been a constant support for innovation in the construction sector in New Zealand. AECFutures have documented a report with aims to provide strategies in supporting innovation in the construction sector. The report has outlined their strategies with its proposed timeline for up to ten years which involves the government, industries and education providers. The technologies that were taken as study cases in this report are within the Industry 4.0 scope which are additive manufacturing (3D houses) and autonomous robots (McMeel and Sweet, 2016).

3.4 Food and beverage industry

With the incorporation of Industry 4.0 technologies in the food production lines, factories could be 80% smaller and lead to a safer operating environment and improvements in product shelf-life ('MEET APRIL, the World's Most Famous Robotic Chef', 2017). The Automated Processing Robotic Ingredient Loading, or APRIL, is a fully automated robotic system that could prepare ingredients similarly to professional chefs at an industrial scale. Developed by the University of Lincloln's National Centre for Food Manufacturing, it is designed to boost production and efficiency while maintaining the standard of the food produced. The invention of APRIL has been shortlisted for the World Food Innovation Awards in 2017 for the 'Best Technology Innovation' ('MEET APRIL, the World's Most Famous Robotic Chef', 2017).

Testo Saveris 2 ensures efficient monitoring and documentation of all refrigerated and heated food. With the new Food Act, businesses in the food sectors have benefited from this technology as it ensures they comply with the new Act. The Testo Saveris 2 allows users to log temperature and humidity levels easily to its international approved software. With the software, this eliminates the risk for businesses from any cyber security threats. The Testo Saveris 2 records the temperatures and humidity to their own designed cloud which is later compared to the values set by the Act. When the values recorded exceed the limit value, users receive notifications via email or phone text message ('Are You Following the New Regulations?', 2017).

Festo is a worldwide supplier of automation technology with the aim of maximising productivity and competitiveness for their customers (Didactic, 2017). In a production line, they offered a series of equipment that could reduce the length of planned downtimes such as cleaning the system or scheduled maintenance. Their technologies improved the performance and quality of the products by giving real time updates. The equipment involved sensors and various types of valves that are integrated in a production line and work autonomously as they provide real time information ('Dairy', n.d.).

S. Wilcox and Sons have been an integral part in the New Zealand's dairy industry with their potatoes, onions and carrots production sales. They are involved in the entire supply chain of their own products which start from the growing phase until the transporting process. Technology has been an important factor in the increase of their production. Drones were used to check crops for quality and growth. The information collected from the sensors equipped at the drones have been able to make the farmers to reduce cost, improve efficiency and optimise the number of staffs and machines (Ministry of Business, Innovation and Employment, 2013).

3.5 Dairy industry

Dairy industry is one of the major exports with an estimated revenue of 12 billion dollars. This industry has shifted their business models to a more Industry 4.0-based paradigm for better and more effective management of resources. Automated Technologies is a New Zealand company which specialises in industrial automation. In the dairy sector, it worked with OnFarm solutions by developing teats sprayers to help treat mastitis in cows. Equipped with their control system, the teats sprayer can flexibly travel between each cow's legs which is easier in comparison to the stationary and conventional methods ('Machinery Build for Your Needs, 2017).

By using cloud computing, OnFarm solutions provide real-time updates of the condition at the farms via an app that could be downloaded on smartphones. With an interacting user interface, the farmers have more information and control over the farm even though they are not physically present on-site (OnFarm Datachain, 2013). New Zealand diary industry with early adoption of farm and national level data has used the information through herd testing and setup of the dairy core database. In 2015, an automatic milking systems (AMS) was adopted on around 20 New Zealand farms (Dairy Tomorrow, 2017). That produces large number of benefits such as increased production efficiency and less rigidity around milking schedules. Recently, some robotics are installed in main pastoral farm systems for prevision dairy farming.

4 Opportunities for New Zealand dairy industry

This section will focus on exploring the vast opportunities for New Zealand dairy industry by implementing the Industry 4.0 related technologies. Two Industry 4.0 technologies that are discussed and applicable for dairy industry are IoT and autonomous robot.

4.1 Application of IoT in dairy industry

IoT is the interconnection of networked devices for sharing information through various communications (Zhong et al., 2017d). This enables to sense and collect data and then share it across the internet which is then to be processed and utilised for different purposes. It is the ability to transfer data over a network without requiring human-to-human or human-to-computer interactions. It consists of electronic sensors, chips, microprocessors that have functionality to align with mobile phones (Zhong et al., 2017b). So, it is easy to monitor and control the daily activities, working ecosystem and many other tasks. An increasing number of machines and objects are now embedded with

sensors or actuators that can communicate over the internet. Collectively, they make up the IoT (ETSI, 2017).

4.1.1 Management of health and productivity of cows

The process of tracking each cow individually to manage larger herds with fewer employees is complex. However with the use of IoT, three key stages that dairy farmers can monitor and manage to improve performance could be facilitated: feeding, fertility and health. Sensors provide continuous streams of data regarding the milk output of cows, their heat, waste, activity or toxins released. This data can be stored locally and uploaded into cloud-based management systems for remote monitoring. Farmers are able to make real time data-based decisions to significantly improve reproductive performance and cow health management.

This process can be simplified as follows:

1 Heat monitoring will be enabled by using sophisticated technologies like ankle, collar or ear tags which can monitor activity related to heats and transmit data to a system to help identify optimal windows for artificial insemination.

2 Milk monitoring uses some sensors to get the temperature and density in real time that will help identify and track milk quality and health issues.

3 Weight monitoring is enabled by making a cow walk over scales in parlours that provide analysis for feeding strategies.

4 Calving monitoring is facilitated by tracking the progress of pregnant cows and alert farmers to impending labour. One big reason that dairy cows must constantly be in a cycle of getting pregnant and giving birth to produce milk is because there is only a short window for successful insemination when a cow goes into heat.

4.1.2 Identification of issues

Health monitoring systems will alert the farmer and help detect issues as early as possible. This includes the use of sensors to track movement, bodily functions such as rumination, feeding, head position and restlessness and identify disease, lameness and other health indicators. This will help provide an overall health assessment for each cow (Grant Thornton, 2014).

IoT can help farmers to be more productive by expanding their operations and taking better care of their livestock which is critical to the future of the dairy industry (Grant Thornton, 2014; Heikell, 2015). Dairy monitors exist to provide accurate oestrus detection, health analysis and location services for cows or cattle. These devices promise to free up labour time for dairy farmers, improve production per animal and save a significant amount of cost by optimising their breeding cycles (Badminton, 2016).

IoT provides a greater transparency of what is happening with the cows and the environment instantly. Apart from maintaining the health of cows, it is very important to maintain the surroundings. Having sensors in the farm will help track the usage of fertilisers thus helping to eliminate its wastage and improve the productivity. These sensors will also help to keep track of the water usage. Additionally, having ankle, collar or ear tags will help keep the cows in the desired area for grazing. Any area that is

unsuitable will be directly relayed over through the tags and prevent them from crossing the desired boundary area.

4.2 Application of autonomous robots in dairy industry

In dairy industry, many farm owners have applied autonomous robots in various tasks. There is a massive potential in connecting different machines together. Currently, robots are used by farmers for example the rotary milking machine is integrated into a system where it is only run with minimal human interference. The key to Industry 4.0 is to allow different machines to work together and this can be achieved through the autonomous feature of robots.

4.2.1 Automated milking system

In this system, each cow in the dairy yard moves to one milking points on the rotary platform. As the platform rotates, robotic arms wash the teats and attach the cups. Laser scanning sensors make sure the cups go in the right places. The cups squeezed the teats so that the milk flows through hoses and into a holding tank for analysis. When the computer senses that the flow has slowed to a trickle, the cows is unhooked, cleaned up and set loose to make room for the next one. The milk is then extracted, the teats disinfected, and the cups are flushed.

The process usually takes about eight minutes and as the cow steps off the revolving platform and into a yard. It receives a feed reward before being allowed enter into fresh pasture. Each cow is identified by a dongle around its neck or RFID tags that electronically records and transmits the time and volume of its last milking (Daley, 2016). Sensors on the drafting gates that separate the dairy yards from the pasture read each cow's data. If the cow is recently being milked, it is sent back to the pasture. All of this can be remotely controlled by the farmer along with checking of yields and production mechanics on a smart device. They only need to attend the dairy in case of a malfunction, alerted by an automated phone call or text. If something in the system is not right such as blood detection in the milk, farmers will get a robo-call on their smartphones. They even can use an app to fine-tune the system, without even setting foot in the barn (Boyle, 2016).

4.2.2 Autonomous vehicles and gate for sheep herding

The autonomous vehicles would be relatively slow moving and programmed to follow exact tracks to shift herds of cows with minimal stress. These vehicles can also be used to move the reluctant cows from the paddock to the dairy. Automatic gates on each paddock would open and close when the tags are detected. Ear tag scanner mounted on this machine would scan the paddocks to check for remaining cows (Lambert, 2012). The autonomous vehicles use some Industry 4.0 related technologies such as simulation, computer vision and motion control for enabling the functionalities.

Some problems are identified in the New Zealand dairy industry and the autonomous robots' concept could help for solving them:

a Inexperienced labour or high salary

It is common in New Zealand that diary industry is becoming difficult to have experienced workers. There is also less interest from the young generation to involve in the dairy farms. To resolve these challenges, autonomous robots would be a possible and feasible solution for New Zealand. Automated rotary milking and automated vehicle involve less workers in the whole process. Through automation, the likelihood of injuries while shifting of herds could lessen significantly.

b Production fluctuation and error proofing

One of the main concerns in the dairy industry is the fluctuation in production which is commonly caused by the differences employed workers and the inexperience in handling the process. The systematic process done by the autonomous robots ensures a constant work rate so the production fluctuation could be reduced as much as possible. Apart from that, the whole process of automated rotary milking for example ensures a fixed quality product and increases production efficiency as the process is continuous.

c Control in budget

High costs involved in running the whole farm becomes a concern for the farmers as they are facing the risks of return of their investment if the labour costs are becoming increasing high. The application of autonomous robots in rotary milking and shifting of herds can increase the production efficiency on one hand. On the other hand, it can ensure a more qualified process and low worker involvement. The application of Industry 4.0 concepts such as autonomous robots results in an elimination of unnecessary overhead costs.

5 Discussions on worldwide perspective

Industry 4.0's importance and potential have been recognised worldwide (Trappey et al., 2017a). Respondents expect to significantly increase their portfolios of digital products and services; more than twice as many expect to be at an advanced level in this area by 2020 compared to today. Similarly, almost three-quarters of companies expect to have highly digitised horizontal and vertical value-chain processes in five years.

Companies that successfully implement Industry 4.0 gained large number of profits through improved productivity and reduced costs. The companies surveyed by PWC expect to increase annual revenues by an average of 2.9% and reduce costs by an average of 3.6% per annum. The companies expect to have US $421 billion in cost reductions and US$493 billion in increased annual revenues per annum for the next five years (Geissbauer et al., 2016). If even half of these expectations are met, Industry 4.0 will fundamentally reshape the competitive landscape and bring fundamental change to established industries. Several case studies, according to 2016 Global Industry 4.0 Survey, suggest the following trends:

- The biggest implementation challenge is not related to specific technologies, while it is a lack of digital culture and technical expertise in their organisation.
  Implementation of the right technologies is important, ultimate success or failure will

not solely depend on specific sensors, algorithms or analytics tools, but on a broader range of people-focused factors such as acceptance of new technologies and willingness of upgrading.

- Data fuels Industry 4.0 and successful data analytics is the prerequisite for ultimate implementation of digital enterprise applications. Data capture and collection plays an important role in enterprise decision-makings where advanced models will be quipped by making full use of the data from various sensors, digital devices and IT systems.
- Industrial companies need to develop robust organisational structures that support data analytics as an enterprise-level capability. It is reported that 38% of companies currently rely on selective and ad-hoc capabilities of single employees.
- Industry 4.0 will create digital networks and ecosystems that in many cases will span the globe, but still retain distinct regional footprints. Both developed and developing markets stand to gain dramatically. Companies in Japan and Germany are the furthest along in digitising internal operations and partnering across the horizontal value chain. With high investment in technology and employee training, their digital transformation primarily achieved in terms of gains in operational efficiency, cost reduction and quality assurance. China's industrial companies stand out in all aspects of digitisation such as cost reductions as well as increased digital revenues through to 2020. China is one of the countries that stand to gain the most from automating and digitising labour-intensive manufacturing processes. In addition, Chinese companies are highly flexible and open to digital change due to the increasing labour costs and global competitions.
- Industry 4.0 investments are significant, and it is estimated that global industrial products companies will invest US $907 billion per year through to 2020. The major focus of this investment will be on digital technologies like sensors or connectivity devices, as well as on software and applications like manufacturing execution systems (MES). In addition, companies are also investing in training employees and driving organisational change.

With the increasing dairy demand, the importance of dairy Industry 4.0 has been recognised world-wide. For instance, in farms, the technologies of dairy Industry 4.0 have been widely utilised:

- smart sensors are used to monitor the health and productivity of cows
- during milk transport process, optimised route and suitable storage temperature have been precisely set down for safe and efficient transport
- in modern milk factories, intelligent data platform and automation have been successfully applied to manage milk product quality.

With the constant progress of technologies, more and more solutions of 'Industry 4.0' have been implemented in the dairy field to improve the efficiency and automation.

1 Health management in dairy industry: SmaXtec Animal Care Sales GMBH has offered an integrated solution for monitoring herd, including smart sensors, artificial intelligence, wireless communication, and software tools. According to this technology, the cows' individual information, such as heat, calving, health, and

feeding, can be easily tracked instantly. It helps farmers to make the proper decisions in time to improve animal health status and farm efficiency (Mena Report, 2017).

2 Transport system in dairy industry: The ONTARIO Milk Transport Association (OMTA) has established a comprehensive tracking system for farmers, transporters, and milk product manufacturers. Through scanning barcode at farms and plants, drivers can confirm the identification of milk's sample and grade to make sure a suitable transport setting for the volume and temperature. Meanwhile, the mileage and time spent on the road can be uploaded to the system to prevent unnecessary trips for couriers (Modern Bulk Transporter, 2000).

3 Quality control and automated operation in diary industry: Based on Siemens Simatic IT Unilab platform, Mengniu dairy factory has developed a set of lab system: Laboratory Information Management System (LIMS) to achieve the target of precise and efficient quality control. On one hand, this system can trace the test data from each batch of milk products and quality issues during the whole production process. On the other hand, over 90% of test data is automatically collected and calculated for quality control. Moreover, Siemens Totally Integrated Automation (TIA) solutions have been applied to production lines, and Mengniu uses the programmable logic controller (PLC) to regulate operating parameters on the production lines accurately and efficiently to control conveying speed on the package lines (Siemens, 2017).

4 Livestock management in diary industry: The world's first herding robot, Swagbot, which is developed by Australian Centre for Field Robotics at the University of Sydney, has been proven successful in trials to manage livestock on sheep and cattle. The robot can herd cattle and navigate its way around ditches, logs, swamps, and other obstacles. Additionally, it can pull heavy trailers and traverse across rugged terrain (Dvorsky, 2016).

5 Efficient land usage in diary industry: In New Zealand, a team from AgResearch and Lincoln University, designed a prototype: Agri-Rover which is reliable and robust for farm implementation. Its features include checking the length of pasture, weed control, bringing cows to the shed, sensing soil for fertiliser application and adding nitrogen inhibitors to urine patches on dairy farms (Watson, 2008).

6 Conclusions

Currently, the problems caused by the constraints of Industry 3.0 technologies have been identified for Dairy Industry, and New Zealand diary industry is actively seeking solutions. The advantages created by Industry 4.0 related technologies such as its ability to reduce cost, increase efficiency and provide greater accessibility to information are realistic and attractive, hence, many companies are interested in implementing these in their workplace.

Some contributions are as follows. First of all, the detailed study and research on the Industry 4.0 technology has led to several solutions that seems most beneficial at solving the current diary industry problems. These include monitoring systems for dairy farms through the application of IoT and the use of autonomous robots. Secondly, although this

paper focuses on the implementation of Industry 4.0 in the scope of dairy industry, it is evident that New Zealand companies from other sectors such as manufacturing, information and communication technology, construction, food and beverages industry are also incorporating a strategic guide to stay updated with the journey towards Industry 4.0. This is due to the huge benefits of Industry 4.0 technology that will improve the performance and efficiency of New Zealand industries.

The successful cases of dairy industry worldwide, like the advanced technologies of dairy Industry 4.0 being applied to all-day monitor cows' health in farms, build an effective tracking system during milk transport process, and automatically manage milk product quality and productivity. It is expected that these technologies can bring abundant benefits into New Zealand dairy industry. For the future of dairy industry and the investment on it, it's essential that dairy companies need to develop a robust digital culture and make sure change is driven by clear leadership.

References

Almada-Lobo, F. (2016) 'The Industry 4.0 revolution and the future of manufacturing execution systems (MES)', *Journal of Innovation Management*, Vol. 3, No. 4, pp.16–21.

Are You Following the New Regulations? (2017) 16 June [online] http://www.foodtechnology.co.nz/content/are-you-following-the-new-regulations/ (accessed 17 April 2017).

Badminton, N. (2016) *The Future of Dairy: Things, Robots and Big Data*, 1 February [online] http://www.progressivedairycanada.com/topics/management/the-future-of-dairy-things-robots-and-big-data (accessed 17 April 2017).

Boyle, A. (2016) *How Robots are Taking Over the Milking Parlour, and Why That's Good for Cows and Farmers*, 28 January [online] https://www.geekwire.com/2016/how-robots-are-taking-over-the-milking-parlor-and-why-its-good-for-the-cows/ (accessed 20 April 2017).

Brettel, M., Friederichsen, N., Keller, M. and Rosenberg, M. (2014) 'How virtualization, decentralization and network building change the manufacturing landscape: an Industry 4.0 perspective', *International Journal of Mechanical, Industrial Science and Engineering*, Vol. 8, No. 1, pp.37–44.

Callaghan Innovation (n.d.) *Production Machinery Limited* [online] https://www.callaghaninnovation.govt.nz/incite/production-machinery-limited (accessed 20 April 2017).

Dairy (n.d.) [online] https://www.festo.com/cms/en-nz_nz/18992.htm (accessed 20 April 2017).

Dairy Tomorrow (2017) *Dairy Industry Strategy Refresh 2017*, November [online] http://www.dairytomorrow.co.nz/wp-content/uploads/2017/11/dairy-strategy-2017-a4-booklet-part-2-stragegy-refresh-2017.pdf (accessed 28 April 2017).

DairyNz (2015) *QuickStats About Dairying – New Zealand*, November [online] https://www.dairynz.co.nz/media/3142896/QuickStats-about-dairying-new-zealand.pdf (accessed 28 April 2017).

Daley, P. (2016) *Transforming the Bush: Robots, Drones and Cows That Milk Themselves*, 4 June [online] https://www.theguardian.com/australia-news/2016/jun/04/transforming-the-bush-robots-drones-and-cows-that-milk-themselves (accessed 28 April 2017).

Didactic, F. (2017) *Qualification for Industry 4.0. When Industry 4.0 is all about Future Production Processes, then the Centrepiece is the Smart Factory*, pp.1–16 [online] https://www.festo-didactic.com/download.php?name=brochure_Qi4_screen_full_56759en.pdf&c_id=1100&file=brochure_qi4_screen_full_56759en.pdf (accessed 28 April 2017).

Douphrate, D.I., Lunner Kolstrup, C., Nonnenmann, M.W., Jakob, M. and Pinzke, S. (2013) 'Ergonomics in modern dairy practice: a review of current issues and research needs', *Journal of Agromedicine*, Vol. 18, No. 3, pp.198–209.

Dvorsky, G. (2016) *This Aussie Cattle-Herding Robot Will Put Dogs Out of Work*, 15 Juy [online] https://www.gizmodo.com.au/2016/07/this-aussie-cattle-herding-robot-will-put-dogs-out-of-work/ (accessed 10 May 2017).

ETSI (2017) *Internet of Things* [online] http://www.etsi.org/technologies-clusters/technologies/internet-of-things (accessed 10 May 2017).

Geissbauer, R., Vedso, J. and Schrauf, S. (2016) *Industry 4.0: Building the Digital Enterprise* [online] https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf (accessed 10 May 2017).

Grant Thornton (2014) *Investing in the Internet of Things Spotlight on Technology in the Dairy Industry* [online] https://www.grantthornton.ie/globalassets/1.-member-firms/ireland/ insights/publications/grant-thornton-investing-in-the-internet-of-things-spotlight-on-dairy.pdf (accessed 10 May 2017).

Heikell, L. (2015) *Connected Cows Help Farms Keep Up with the Herd*, 17 August, [online] https://news.microsoft.com/features/connected-cows-help-farms-keep-up-with-the-herd/#hEzED31EeEVJ6LTJ.97.97 (accessed 10 May 2017).

Ivanov, D., Dolgui, A., Sokolov, B., Werner, F. and Ivanova, M. (2016) 'A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0', *International Journal of Production Research*, Vol. 54, No. 2, pp.386–402.

Jazdi, N. (2014) 'Cyber physical systems in the context of Industry 4.0', *Automation, Quality and Testing, Robotics, 2014 IEEE International Conference on*, IEEE.

Kagermann, H., Helbig, J., Hellinger, A. and Wahlster, W. (2013) 'Recommendations for implementing the strategic initiative INDUSTRIE 4.0: securing the future of German manufacturing industry', Final report of the Industrie 4.0 Working Group, Forschungsunion.

Kordia (2016) *Kordia and Thinxtra Internet of Things Network Passes*, 22 August, [online] https://www.kordia.co.nz/news-and-views/kordia-and-thinxtra-internet-of-things-network-passes-half-way-mark (accessed 10 May 2017).

Lambert, P. (2012) *Challenges and Opportunities for Large Scale Dairies*, Nuffield Australia Project Number: 1109, Nuffield Australia, Australia.

Lee, J., Bagheri, B. and Kao, H-A. (2015) 'A cyber-physical systems architecture for industry 4.0-based manufacturing systems', *Manufacturing Letters*, Vol. 3, pp.18–23.

Lee, J., Kao, H-A. and Yang, S. (2014) 'Service innovation and smart analytics for industry 4.0 and big data environment', *Procedia CIRP*, Vol. 16, pp.3–8.

Li, S., Xu, L.D. and Zhao, S. (2018) '5G internet of things: a survey', *Journal of Industrial Information Integration*, Vol. 10, pp.1–9.

Liu, C.H. and Zhong, R.Y. (2017) 'Internet of things for manufacturing in the context of Industry 4.0', *Transdisciplinary Engineering: A Paradigm Shift Advances in Transdisciplinary Engineering*, Vol. 6, No. 6, pp.1013–1022.

Lu, S., Xu, C., Zhong, R.Y. and Wang, L.H. (2017) 'A RFID-enabled positioning system in automated guided vehicle for smart factories', *Journal of Manufacturing Systems*, Vol. 44, pp.179–190.

Lu, Y. (2017a) 'Industry 4.0: a survey on technologies, applications and open research issues', *Journal of Industrial Information Integration*, Vol. 6, pp.1–10.

Lu, Y. (2017b) 'Cyber physical system (CPS)-based industry 4.0: a survey', *Journal of Industrial Integration and Management*, Vol. 2, No. 3, p.1750014 (1–57).

Machinery Build for Your Needs (2017) [online] http://www.automatedtechnologies.co.nz/industrial.php (accessed 10 July 2017).

Mcbeth, P. (2017) 'Huawei to invest $400m in New Zealand to drive R&D, build data centre', *NBR* 22 March [online] https://www.nbr.co.nz/article/huawei-invest-400m-new-zealand-drive-rd-build-data-centre-b-200951# (accessed 10 July 2017).

McMeel, D and Sweet, K. (2016) 'Roadmap for supporting innovation in the New Zealand construction sector', *Report ER11*, University of Auckland, New Zealand.

MEET APRIL, the World's Most Famous Robotic Chef (2017) 22 March [online] http://www.foodtechnology.co.nz/content/meet-april-the-worlds-most-famous-robotic-chef/ (accessed 10 July 2017).

Mena Report (2017) *ProDairyWelfare: smaXtec 4.0 Multifunctional Dairy Cattle Sensor System for a Proactive Productivity and Health Management in Dairy Farming*, 3 March [online] http://ezproxy.auckland.ac.nz/login?url=http://go.galegroup.com.ezproxy.auckland.ac.nz/ps/i.do?p=AONE&sw=w&u=learn&v=2.1&it=r&id=GALE%7CA484825089&asid=edbfed03187b24bf7ed1ad0b5e2c6a83 (accessed 10 July 2017).

Ministry of Business, Innovation and Employment (2013) *The New Zealand Sector Report (2013 report)*, Ministry of Business, Innovation & Employment, New Zealand.

Modern Bulk Transporter (2000) *OMTA Assists Ontario Dairy Industry In Adopting Internet Tracking System*, August, [online] http://ezproxy.auckland.ac.nz/login?url=http://go.galegroup.com.ezproxy.auckland.ac.nz/ps/i.do?p=ITOF&sw=w&u=learn&v=2.1&it=r&id=GALE%7CA64458423&asid=e79ead95e42c870aa4dcb797f635bec1 (accessed 10 July 2017).

Moss, S. (2017) 'Huawei to spend $281.8m on networking and cloud in New Zealand', *Datacenter Dynamics*, 23 March [online] http://www.datacenterdynamics.com/content-tracks/design-build/huawei-to-spend-2818m-on-networking-and-cloud-in-new-zealand/98035.fullarticle (accessed 10 July 2017).

New Zealand Dairy Statistics (2015–2016) *QickStates about dairying – New Zealand* [online] https://www.dairynz.co.nz/media/5418041/quickstats-new-zealand-2015-16.pdf (accessed 10 July 2017).

OnFarm Datachain (2013) [online] http://www.onfarmsolutions.com/products-ofs-datachain.html (accessed 10 July 2017).

Paredes, D. (2016) *Industrie 4.0: How CIOs Can Prepare for the Fourth Industrial Revolution*, 26 May [online] https://www.cio.co.nz/article/575733/industrie-4-0-how-cios-can-prepare-fourth-industrial-revolution/ (accessed 10 July 2017).

Pilz (n.d.) *The Production System of the Future – Modular and Extendible* [online] https://www.pilz.com/en-NZ/products-solutions/industry-4-0 (accessed 10 July 2017).

Rauch, E., Dallasega, P. and Matt, D.T. (2017) 'Distributed manufacturing network models of smart and agile mini-factories', *International Journal of Agile Systems and Management*, Vol. 10, Nos. 3–4, pp.185–205.

Siemens (2017) *'Dairy Industry 4.0': The Future is Now* [online] http://w2.siemens.com.cn/stories/StoryShow/FindStory/27?culture=en-US (accessed 10 July 2017).

Trappey, A.J., Elgh, F., Hartmann, T., James, A., Stjepandic, J., Trappey, C.V. and N. Wognum (2017a) 'Advanced design, analysis, and implementation of pervasive and smart collaborative systems enabled with knowledge modelling and big data analytics', *The Journal is Advanced Engineering Informatics*, Vol. 33, pp.206–207.

Trappey, A.J., Trappey, C.V., Govindarajan, U.H., Chuang, A.C. and Sun, J.J. (2017b) 'A review of essential standards and patent landscapes for the internet of things: a key enabler for Industry 4.0', *Advanced Engineering Informatics*, Vol. 33, pp.208–229.

Wallis, R., Stjepandic, J., Rulhoff, S., Stromberger, F. and Deuse, J. (2014) 'Intelligent utilization of digital manufacturing data in modern product emergence processes', *Proceedings of the 21st ISPE Inc. International Conference on Concurrent Engineering*, CE 2014, IOS Press, Amsterdam, pp.261–270.

Wang, S.Y., Wan, J.F., Zhang, D.Q., Li, D. and Zhang, C.H. (2016) 'Towards smart factory for Industry 4.0: a self-organized multi-agent system with big data based feedback and coordination', *Computer Networks*, Vol. 101, pp.158–168.

Watson, J. (2008) 'Farm mechanisation', *Te Ara - the Encyclopaedia of New Zealand*, 24 November [online] https://teara.govt.nz/en/farm-mechanisation/page-5 (accessed 17 July 2017).

Zhong, R.Y. and Ge, W. (2018) 'Internet of things enabled manufacturing: a review', *International Journal of Agile Systems and Management*, Vol. 11, No. 2, pp.126–154.

Zhong, R.Y., Dai, Q., Qu, T., Hu, G. and Huang, G.Q. (2013) 'RFID-enabled real-time manufacturing execution system for mass-customization production', *Robotics and Computer-Integrated Manufacturing*, Vol. 29, No. 2, pp.283–292.

Zhong, R.Y., Huang, G.Q., Lan, S.L., Dai, Q.Y., Xu, C. and Zhang, T. (2015) 'A big data approach for logistics trajectory discovery from RFID-enabled production data', *International Journal of Production Economics*, Vol. 165, pp.260–272.

Zhong, R.Y., Lan, S., Xu, C., Dai, Q. and Huang, G.Q. (2016a) 'Visualization of RFID-enabled shopfloor logistics big data in cloud manufacturing', *The International Journal of Advanced Manufacturing Technology*, Vol. 84, No. 1, pp.5–16.

Zhong, R.Y., Newman, S.T., Huang, G.Q. and Lan, S.L. (2016b) 'Big data for supply chain management in the service and manufacturing sectors: challenges, opportunities, and future perspectives', *Computers & Industrial Engineering*, Vol. 101, pp.572–591.

Zhong, R.Y., Peng, Y., Xue, F., Fang, J., Zou, W., Luo, H., Ng, S.T., Lu, W., Shen, G.Q. and Huang, G.Q. (2017a) 'Prefabricated construction enabled by the Internet-of-Things', *Automation in Construction*, Vol. 76, pp.59–70.

Zhong, R.Y., Wang, L.H. and Xu, X. (2017b) 'An IoT-enabled real-time machine status monitoring approach for cloud manufacturing', *Procedia CIRP*, Vol. 63, pp.709–714.

Zhong, R.Y., Xu, C., Chen, C. and Huang, G.Q. (2017c) 'Big data analytics for physical internet-based intelligent manufacturing shop floors', *International Journal of Production Research*, Vol. 55, No. 9, pp.2610–2621.

Zhong, R.Y., Xu, X. and Wang, L.H. (2017d) 'IoT-enabled smart factory visibility and traceability using laser-scanners', *Procedia Manufacturing*, Vol. 10, pp.1–14.

Zhong, R.Y., Xu, X., Klotz, E. and Newman, S.T. (2017e) 'Intelligent manufacturing in the context of Industry 4.0: a review', *Engineering*, Vol. 3, No. 5, pp.616–630.