Enabling a digital transformation *in Agriculture*

A DIGITAL MATURITY INDEX AND ASSESSMENT TOOL FOR THE AGRICULTURAL INDUSTRY

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Executive Summary

Digital technologies could lift the gross value of production (GVP) of the Australian agricultural sector by $20.3 billion, and the broader Australian economy by $24.6 billion (Perrett, Heath, Laurie & Darragh, 2017). While agricultural digital technologies are already well advanced and available in the marketplace, research has revealed that adoption and utilisation remains low across the industry (McKinsey et al., 2017; Skinner, Wood, Leonard & Stollery, 2017; Zhang, Baker, Jakku & Llewellyn, 2017). To achieve the $100 billion industry goal by 2030 (National Farmers Federation, 2018), the industry needs to embark on a digital transformation journey.

To ensure that the journey of digital transformation is purposeful and effective, it is important to first undertake an assessment of the industry to identify areas of digital strength and areas for development. The development of a digital maturity index and assessment tool is considered a necessary first step for digital transformation. CSIRO has developed a world-first digital maturity index and assessment tool specifically for agriculture, which encompasses five key pillars.

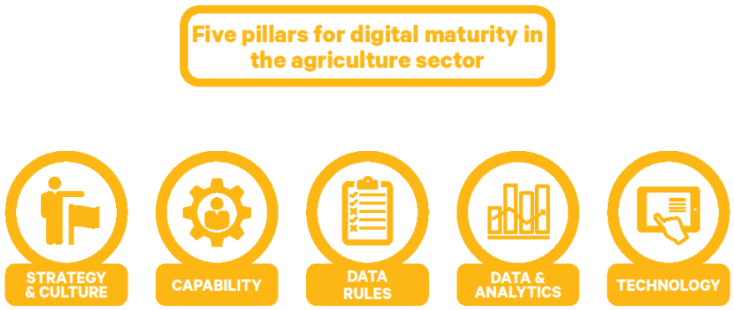

Figure 1 Five pillars of digital maturity for the agriculture industry

The index and assessment tool will serve both a diagnostic and, monitoring and evaluation function for digital transformation. It will help agribusinesses and individual agriculture sectors evaluate their current levels of digital maturity, identify areas of strength and weakness, as well as assist them in setting goals, and in developing and evaluating targeted digital-improvement initiatives. It also can help inform strategies and a broader roadmap at the industry level. When the assessment tool is administered over time, it can also monitor progress towards targets. Ultimately, this assessment will help the agriculture industry develop a systematic digital strategy that, by design, should transform the industry from one that is ad hoc, to one that is purposeful and impactful.

The index's assessment tool will be made freely available on the RDCs websites, for agribusinesses to complete and receive personalised feedback on their digital strengths and areas for development.

A digital maturity index for agriculture

To contribute to the digital transformation journey, the current project aims to develop a digital maturity index and associated assessment tool to measure the digital maturity of agribusinesses. Digital maturity is defined as "a continuous and ongoing process of adaptation to a changing digital landscape" (p. 5), with maturity depicting a learned ability to respond to the environment in an appropriate manner (Kane, Palmer, Phillips, Kiron & Buckley, 2017). Digital maturity reflects how organizations systematically prepare to adapt to ongoing digital change consistently, which goes far beyond just implementing new technology. It requires key digital building blocks that support whole of system change.

The development of a digital maturity index and assessment tool is considered a necessary first step for digital transformation. The tool will serve a diagnostic and, monitoring and evaluation function for digital transformation. It helps agribusinesses and individual agriculture sectors to evaluate their current levels of digital maturity, identify areas of strength and weakness, as well as assist them in setting goals, and in developing and evaluating targeted digital-improvement initiatives. When the assessment tool is administered over time, it can also monitor progress towards targets. Ultimately, this assessment will help the agriculture industry develop a systematic digital strategy that, by design, should transform the industry from one that is ad hoc, to one that is purposeful and impactful.

To develop a digital maturity index for the Australian agricultural industry, we conducted a detailed review of existing digital maturity models and related literature across industries globally. A digital maturity index for the agricultural industry was developed (see Appendix A). The second phase of the Digital Maturity project is to develop an assessment tool to assess the pillars of the digital maturity index as well as define the digital maturity stages for each pillar.

In the current report, we first outline the digital maturity index and define the stages of digital maturity. A matrix of maturity stages against each pillar of the digital maturity index is then presented, describing the status of each maturity stage for each pillar. Finally, the assessment tool will be presented.

Five pillars of agricultural digital maturity index

Through reviewing existing digital maturity models across various industries, we have identified common digital building blocks that comprise the foundation of successful digital transformation (for details, see Appendix A). In summary, digital transformation requires agribusinesses to reinvent their business at its core, which not only involves changes in technology, operations, capabilities and infrastructure, but also a new mindset that clearly positions 'digital' as a central part of the business' vision and strategy. Table 1 presents the key pillars for a digital maturity index for agriculture. In the assessment, the term 'agribusiness' is used to include producers, consultants, processors, technology & service providers, logistics, marketers/merchants, Rabobank (rural bank for agribusinesses), and research & development corporations.

Table 1 Pillars comprising an assessment of digital maturity in agriculture

Pillar	Description of the pillar	Description of a digitally transformed agribusiness
Strategy & Culture	This pillar focusses on (1) the agribusiness' priority and planning towards digitally transforming its business, and (2) the enabling environment promoted by the agribusiness and its industry.	The agribusiness places a high priority and value on digitising and automating the business. It has a clearly-defined path towards a digital future where utilising digital technologies and automating business operations is key for business growth and transformation. The agribusiness has a culture that fosters innovation and collaboration, which is strongly supported by a favourable, enabling environment from industry.
Technology	This pillar focusses on (1) communication infrastructure that supports agribusiness' data and digital technology needs, (2) in-business digital technologies that assist business operations and decision-making, and (3) new digital technologies in the market place.	The agribusiness' communication infrastructure fully supports its data and digital technology needs. Digital technologies are effective and fully utilised in the business, coupled with strong technical support. The agribusiness completely understands, and finds it easy to choose, new digital technologies that meet their needs.
Data & Analytics	This pillar focusses on (1) the collection and use of data, (2) analytical tools for supporting data-driven decision-making, and (3) data interoperability across the supply chain.	The agribusiness collects all relevant data that are of high quality. All data can be easily accessed in-business and through the supply chain. Data from multiple sources is integrated and analysed to inform decision-making, supported by decision tools and/or systems.
Capability	This pillar focuses on agribusiness' knowledge, skills and abilities in working with digital technologies and data.	The agribusiness has comprehensive knowledge, skills and abilities to fully utilise digital technologies and data for decision-making. The business knows where to source expertise and prioritises upskilling staff.
Data rules	This pillar focusses on data management and sharing to ensure the integrity and security of data.	The agribusiness has well-established systems and allocated staff to manage data. Data sharing between businesses are fully governed by agreements for appropriate use.

Stages of digital maturity

The stages of digital maturity are assessed at the pillar-level, reflecting the 'stage' of digital maturity for each pillar. Hence, the stages of digital maturity specify the characteristics that agribusinesses progressively achieve in their journey towards becoming 'digital'. Scores on all items in each pillar are averaged. The four stages of maturity are as follows:

- 'Emerging'
- 'Transitional'
- 'Competitive'
- 'Transformative'

The description for each of these four stages across the five digital maturity pillars are presented in Table 2.

Table 2 The four stages of digital maturity across the five digital maturity pillars

Pillar	Emerging	Transitional	Competitive	Transformative
Strategy & Culture	The agribusiness places a low priority and value on digitising and automating the business. It has no clear plan or intentions to digitally transform its business. The agribusiness has a conservative culture where innovation and collaboration are hindered. The industry is perceived as not providing support to guide digital transformation.	The agribusiness is starting to value the application of digital technology to their business. However, it is yet to develop a clear action and investment plan for adopting and utilising digital technologies. The agribusiness has a conservative culture where innovation and collaboration are not actively nurtured, nor does its industry actively promote digital innovation.	The agribusiness sees the value in digitising and automating the business. It has developed and enacted a strategic plan for adopting and utilising digital technologies. The agribusiness has a culture that fosters innovation and collaboration, which is supported by an industry that actively promotes digital innovation.	The agribusiness places a high priority and value on digitising and automating the business. It has a clearly-defined path towards a digital future where utilising digital technologies and automating business operations is key for business growth and transformation. The agribusiness has a culture that fosters innovation and collaboration, which is strongly supported by a favourable, enabling environment from industry.
Technology	The agribusiness' communication infrastructure does not support its data and digital technology needs, and the business is yet to take action to improve this infrastructure. There is limited use of digital technologies and technical support is poor. The agribusiness has limited understanding of new digital technologies on the market.	The agribusiness' communication infrastructure barely supports its data and digital technology needs. The business has started to deploy digital technologies. The agribusiness has some understanding of new digital technologies on the market but finds it difficult to choose new technologies that meet their needs.	The agribusiness' communication infrastructure adequately supports its data and digital technology needs. The business deploys digital technologies, coupled with satisfactory technical support. The agribusiness generally understands, and finds it reasonably easy to choose, new digital technologies that meet their needs.	The agribusiness' communication infrastructure fully supports its data and digital technology needs. Digital technologies are effective and fully utilised in the business, coupled with strong technical support. The agribusiness completely understands, and finds it easy to choose, new digital technologies that meet their needs.
Data & Analytics	The agribusiness collects limited data and they are of poor quality. The data are difficult to access in-business and through the supply chain. Decision-making is not data-driven.	The agribusiness collects some relevant data and they are of variable quality. The data cannot be easily accessed in-business and through the supply chain. The agribusiness is starting to use data for decision-making but in a basic way.	The agribusiness collects a lot of relevant data and they are of sound quality. Most of the data can be easily accessed in-business and through the supply chain. Decision-making is supported by data integrated from many sources and decision tools and/or systems.	The agribusiness collects all relevant data and they are of high quality. All data can be easily accessed in-business and through the supply chain. Data from multiple sources is integrated and analysed to inform decision-making, supported by decision tools and/or systems.
Capability	The agribusiness lacks the knowledge, skills and abilities to use digital technologies and manage data. The business has limited understanding of where to source external expertise and does not participate in training opportunities.	The agribusiness has limited knowledge, skills and abilities to use digital technologies and manage data. The business has poor understanding of where to source external expertise and does not actively upskill its staff.	The agribusiness has sound knowledge, skills and abilities to use digital technologies and data for decision-making. The business knows where to source expertise and makes an effort to upskill its staff.	The agribusiness has comprehensive knowledge, skills and abilities to fully utilise digital technologies and data for decision-making. The business knows where to source expertise and prioritises upskilling staff.
Data Rules	The agribusiness does not have established systems or allocated staff for managing data. Data sharing between business is not covered by agreements.	The agribusiness is starting to manage data but not in a systematic way. Data sharing between business is not adequately covered by agreements.	The agribusiness has taken steps to develop a systematic approach to manage data. Data sharing between businesses are largely governed by agreements for appropriate use.	The agribusiness has well-established systems and allocated staff to manage data. Data sharing between businesses are fully governed by agreements for appropriate use.

Assessment tool

This assessment tool has been developed to measure each of the pillars specified in the digital maturity index. Table 3 presents the assessment tool questions and its scoring system.

Table 3 The digital maturity assessment tool

What is the purpose of this assessment tool?	This assessment tool is designed to identify the digital strengths and weaknesses of agribusinesses in the Agricultural industry. By completing the tool, agribusinesses will gain a better understanding of their current digital maturity and areas for improvement. The findings from this assessment may also inform the industry when developing the national digital strategy for Agriculture and associated investment priorities. The tool is developed by CSIRO and funded by 10 Research & Development Corporations (RDCs). It has received ethical clearance from CSIRO's Human Research Ethics Committee (07 3833 5693). The aggregated data may be used by RDCs to inform their strategic planning and researchers to understand the digital maturity in agriculture.
How to complete the assessment tool:	The tool contains 54 questions and should take approximately 15 minutes to complete. It should be completed by business managers who are involved in decision-making. When answering the questions, please think about your business and the digital technologies your business uses. Digital technologies encompass a range of technologies including sensors, apps, GPS, drones, machinery, data analytic tools, visualisation programs, as well as other hardware and software for automating business processes. At the end of the assessment, you will be provided with feedback on the digital maturity of your business.

Pillar 1: Strategy & Culture	13 Qs	Assessment Questions	Response scale
Strategy	P1-1	Our business has a clear plan that shows the path and steps for using digital technologies and data for making business decisions and automating our business operations.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-2	Utilising digital technologies and automating business operations is a core part of our strategy for increasing productivity and competitiveness	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-3	When our business invests in new digital technologies, we choose technologies that will be fit for purpose in the long-term.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-4	Our business constantly looks for new and emerging digital technologies that will improve our business.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-5	Thinking of your business' investment in the next 12-18 months, approximately what percentage will be spent on new digital technologies?	1=0-20%; 2=21-40%; 3=41-60%; 4=61-80%; 5=more than 80%
	P1-6	Our business has a long-term plan for investing in new digital technologies and hiring/upskilling staff with digital capability	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
Culture	P1-7	Staff in our business are encouraged to use and experiment with new digital technologies.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-8	Staff in our business are expected to use data for decision-making.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-9	Staff in our business are encouraged to exchange digital experiences and share insights with other businesses in the industry.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
Industry leadership	P1-10	My industry (e.g., member groups/associations, RDCs, state government departments) actively promotes and demonstrates the value of digital technologies (e.g., supplies information through factsheets and workshops, outlines the benefits and costs of new technologies)	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree

	P1-11	My industry communicates best-practice business strategies to utilise available data and apply analytics for decision-making (e.g., via demonstrations from technology companies and/or leading businesses).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-12	My industry has established networks of people and partnerships that provide strong support to our business on digital technology matters	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P1-13	My industry has provided best practice guidelines on how data should be managed.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
Pillar 2: Technology	**13 Qs**	**Assessment Questions**	**Response scale**
Communication infrastructure	P2-1	We have a good understanding of current and emerging communication options available to our business (e.g., LoRaWAN, 5G, satellite, wifi, radio).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P2-2	Our current communication infrastructure completely meets our needs in relation to coverage and reliability, today and in the foreseeable future.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P2-3	Our current communication infrastructure has the capacity to handle the volumes of data we need (e.g., sending data to, or downloading data from, the cloud).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P2-4	Our business actively seeks understanding and opportunities on how to improve our communication infrastructure (e.g., LoRaWAN, 5G, satellite such as Sky Muster and IPSTAR).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
In-business technology	P2-5	Approximately how much of your business' operations are automated (e.g., invoicing and payment systems, production operations, logistics)?	1=no operations are automated; 3=some; 5=all operations are automated
	P2-6	Thinking of the digital technologies in your business, how easy is it to use them?	1=none of the technologies are easy to use; 3=some technologies are easy to use; 5=all technologies are easy to use
	P2-7	How would you rate the extent to which the digital technologies in your business are being utilised?	1=barely utilised (only basic functions used); 3=moderately utilised (some functions used); 5=fully utilised (all functions used)
	P2-8	How would you rate the technical support your business receives from technology & service providers?	1=very poor; 3=satisfactory; 5=excellent
Technology market place	P2-9	When thinking about purchasing new digital technologies, we find it hard to determine the potential return-on-investment.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree (reverse-coding needed)
	P2-10	We have a good understanding of digital technology options currently on the market (e.g., drones, sensors, robots and apps).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P2-11	Most digital technologies on the market can be easily integrated with what we currently have.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P2-12	It is hard to find new digital technologies to meet our business' needs.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree (reverse-coding needed)
	P2-13	It is difficult to choose which digital technologies to purchase because there are too many options.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree (reverse-coding needed)
Pillar 3: Data & Analytics	**16 Qs**	**Assessment Questions**	**Response scale**
Data	P3-1	Our business collects all the data that we need to make the best possible business decisions (including internal data from sensors and machinery; external data from other businesses and sources such as satellites).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P3-2	How much of the data you collect is stored electronically?	1=hardly any of the data; 3=some of the data; 5=all of the data
	P3-3	How much of your data is stored in the cloud for access by yourself and other businesses (such as your service providers)?	1=none of the data; 3=some of the data; 5=all of the data
	P3-4	How much of the data collected in your business is of high quality and can be readily used for decision-making?	1=hardly any of the data; 3=some of the data; 5=all of the data

	P3-5	How much of the data collected in your business is used for making decisions?	1=hardly any of the data; 3=some of the data; 5=all of the data
	P3-6	We continuously review how we use data and our future data needs for enhancing business operations.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P3-7	Data is highly valued in our business for decision-making.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
Analytics	P3-8	When making decisions, we integrate data from multiple sources to obtain high quality insights (e.g., data from our business, other businesses and/or in the public domain).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P3-9	Our business uses decision support tools or systems for decision making (e.g., soil mapping, feed budgeting tools, enterprise resource planning).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P3-10	Our business uses tools that provide predictions of what might happen in the future to assist with our decision-making (e.g., predictive climate tools, yield forecasting tools).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P3-11	Thinking of the datasets collected by your business, how easily can they be combined for analysis?	1=not easy at all; 3=somewhat easy; 5=very easy
	P3-12	My industry has established digital systems that support the management of large datasets that our business handles	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
Interoperability	P3-13	We interact with other businesses digitally by using system integration platforms such as cloud-based services.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P3-14	When your business is asked to provide electronic data by other businesses (e.g., advisors, wholesalers, retailers, processing businesses, merchants), how often is the data requested in a different format from your own business records?	1=all the time (they request it in different formats); 3=some of the time; 5=never (they request it in the same format)
	P3-15	When your business receives electronic data from other businesses (e.g., advisors, wholesalers, retailers, processing businesses, merchants), how often is the data in a different format from your own business records?	1=all the time (it is in a different format); 3=some of the time; 5=never (it is in the same format)
	P3-16	When you receive data from other businesses, to what extent is the data accurate and consistent over time?	1=never; 3=some of the time; 5=all the time

Pillar 4: Capability	**9 Qs**	**Assessment Questions**	**Response scale**
	P4-1	We have a good understanding of current and emerging digital technologies relevant to our business.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-2	We know where to seek expert assistance on issues related to digital technologies.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-3	We know where to seek expert assistance on how to use data to inform decision-making.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-4	We have staff who are capable of operating digital technologies (including digital devices, apps and machinery) used in our business.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-5	We have staff who are capable of integrating, analysing and interpreting data to inform decision-making	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-6	We have staff who are capable of communicating and engaging with other parties on matters regarding digital technologies.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-7	We have staff who are capable of solving problems that sometimes arise when using digital technologies.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-8	We have staff who are capable of maintaining and storing data in a securely accessible form such as in the cloud.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
	P4-9	How often do staff participate in training courses (e.g., extension events) and/or workshops on how to use digital technologies and data for decision-making?	1=hardly ever; 3=sometimes; 5=always when the opportunity arises

Pillar 5: Data Rules	**3 Qs**	**Assessment Questions**	**Response scale**
	P5-1	Our business has allocated staff who are responsible for managing data.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree

P5-2	Our business has systems in place for managing data to ensure our data remains secure and private (e.g., electronic collection, storage and sharing of data, backing up data, use of strong passwords).	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree
P5-3	When sharing data with other parties, there are agreements in place regarding how the data should be used.	1=strongly disagree; 3=neither agree nor disagree; 5=strongly agree

Demographics	Assessment Questions	Response scale
	These final questions will be used to describe the broader sample of agribusinesses that complete the tool. Your individual responses will be kept private and confidential.	
Business function	What is your main business? (select all that apply)	Farm Supplies (e.g., Seeds, Fertiliser, Pesticide) Farm Consultants (e.g., Agronomists, Veterinarians and Other Specialists) Technology & Service Providers (e.g., Communications, Machinery, Sensors, Digital Technology) Farm Production (e.g., Farming) Storage and Handling (e.g., Purchasing and Supply Logistics) Processing and Manufacturing (e.g., Meat processing; Gin/Mill; Packing house) Packaging and Distribution (e.g., Importing, exporting and wholesaling; Retail management) Transport and Logistics (e.g., Transport and despatch management; Supply, distribution and procurement management) Corporate Services (e.g., Financial management; Advertising and marketing professionals)
Industry sector	What is the main sector of your business? (select all that apply)	Aquaculture (including fishing) Beef Cattle Sheep Meat Sheep Wool Sheep-Beef Cattle Grain-Sheep or Grain-Beef Cattle Pork Rice Sugar Cane Cotton Grain Vegetables Wine Grapes Fruit & Tree Nuts Nursery Production Dairy Poultry (Meat or Eggs)

Business size	How many staff are employed in your business? (including yourself)	1-5 6-10 11-15 16-20 21-30 over 30
Business income	What is your business' annual gross revenue	$0-$100K $100K-$200K $200K-$500K $500K-$1M $1M-$10M Greater than $10M
Age	What is your age?	_____
Gender	What is your gender?	Male Female Prefer not to say
Education	What is your highest level of education?	Did not complete Year 12 Completed Year 12 Post-secondary qualification - agriculture Post-secondary qualification - other Undergraduate degree - agriculture Undergraduate degree - other Postgraduate degree - agriculture Postgraduate degree - other
Postcode	What is your business' postcode?	_____

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Appendix A

Digital maturity in agriculture

Development of an index and assessment tool for measuring digital maturity in the agriculture industry

30th June, 2019

Airong Zhang and Elizabeth Hobman

1 Introduction

1.1 Digital agriculture in Australia

> "Australian agriculture faces unprecedented change, driven by various factors, such as changing global markets, increasing international competition, technological disruption, climate variability and change, water scarcity, and increasing threats from pests and disease." (Ernst & Young, 2019)

As illustrated in this quote, smart farming, digital agriculture or more recently, 'Agriculture 4.0' technologies are among many factors changing the way farm businesses are operated and managed in Australia. Farming machinery, as well as digital devices and technologies, allow for data collection, information processing, and decision support that promote improved farming efficiency and productivity through reduced input costs and increased production (Adrian et al. 2005, Aubert et al. 2012, Bramley, 2009, Jochinke et al. 2007). It has been estimated that the implementation of digital agriculture across all Australian primary production sectors could yield an economic return of $20.3 billion (gross value) (Leonard et al., 2017; Perrett et al., 2017). Not surprisingly, it is considered one of the critical pathways to maintaining Australian agriculture's top quartile position in OECD productivity rankings (Blackburn et al., 2017) and achieve the vision of exceeding $100 billion by 2030 set by National Farmers' Federation's 2030 roadmap (National Farmers' Federation, 2018).

To take full advantage of the value promised by digital technologies, it is recognised that Australian agriculture needs to embark on a 'digital transformation journey'. A review of the current digital landscape reveals that it is in an immature or ad hoc state, with significant underutilisation of data all along the supply chain (Skinner et al., 2017). A range of contributing factors have been identified, including but not limited to unreliable mobile connectivity, complex digital market/technology offerings, distrust in technology and service providers, and a lack of digital skills and capabilities (Leonard et al., 2017; Skinner et al., 2017; Zhang et al., 2017).

1.2 Developing a digital maturity index for agriculture

To contribute to the digital transformation journey, the current project aims to develop a quantitative assessment of digital maturity – that is, to design a Digital Maturity Model with accompanying assessment tool. The establishment of this model and assessment tool is considered a necessary first step within the larger framework of digital transformation as it will serve a diagnostic and, monitoring and evaluation function for digital transformation. Specifically, it will assist individual agriculture sectors to evaluate their current levels of digital capability, identify areas of strength and weakness, as well as assist them in setting goals, and in developing and evaluating targeted digital-improvement initiatives. And when the assessment tool is administered over time, it can monitor progress towards targets. Ultimately, this assessment will

help the agriculture industry to develop a systematic digital strategy that, by design, should transform the industry from one that is ad hoc, to one that is purposeful and takes full advantage of the capabilities of digital technologies.

In developing a digital maturity model, it is first important to understand the fundamental components of what constructs a maturity model. With the understanding that "maturity models describe and determine the state of perfection or completeness of certain capabilities" (Wendler, 2012, p. 1319), it has been proposed that a maturity model should define a set of discrete, sequential levels or stages, describe the development of the entity, and comprise 'measured objects', capabilities, or multi-dimensional criteria that are specific and measurable. Thus, in this report, we develop a digital maturity model that defines digital maturity using multiple dimensions and is measured via an assessment tool that produces a profile of where the industry sits in terms of digital maturity developmental stages, across those dimensions.

As a first step, we review existing digital maturity models/frameworks and related literature to explore digital maturity in general, as well as in specific industries. Insights are drawn from those models and applied to the development of a conceptual digital maturity model for agriculture. In the next phase of the project, quantitative survey questions will be developed to assess the dimensions and thresholds set to determine the digital maturity stages for each dimension.

2 Literature review

There appears to be no universal definition for the concept of 'digital maturity'. It has been described as a process of "how organizations systematically prepare to adapt consistently to ongoing digital change" (Kane, Palmer, Phillips, Kiron & Buckley, 2017, p. 5), with organisations displaying the most advanced adaptation processes classified as having a "maturing" level of digital maturity (Kane et al., 2017). It has also been described much more simplistically as a measure of "how well an entity…is making use of digital technology to attain better performance" (Mettler & Pinto, 2018, p. 133). Digital maturity may also be related to the somewhat narrower concept of information systems or information technology (IS/IT) maturity that explores the adoption and use of IS/IT in organisations (van de Wetering & Batenburg, 2009).

The concept of digital maturity appears to have taken traction in the consulting arena, presumably in response to the very practical needs of government and organisations as they seek to deploy digital technologies and utilise data to boost productivity and efficiency, and ultimately achieve a competitive edge in the global market. This work has yielded several general digital maturity models that describe the development of an organisation or industry or nation as they progress towards digital maturity. Digital maturity also has been a focus of research attention in a more industry-specific way, wherein a maturity model or framework is tailored to the specific digital needs of an industry. Table 1 presents the models/frameworks reviewed across both literature sets.

Table 4 Examples of digital maturity models and measures to assess digital maturity (those shaded are more general digital maturity models)

Name	Author	Dimensions of Digital Maturity	Stages/levels of Digital Maturity	Level of analysis	How assessed	Industry application
Digital Acceleration Index **https://www.bcg.com/en-au/capabilities/technology-digital/digital-acceleration-index.aspx**	Boston Consulting Group	5 dimensions broken down into 26 sub-dimensions. No definitions provided for the dimensions or sub-dimensions. Set vision, strategy and priorities (example sub-dimension: Vision) Build new businesses and ventures (example sub-dimension: Prototyping) Digitize customer engagement and core offering (example sub-dimension: Digital data-driven marketing) Build digital capabilities (example sub-dimension: Digital organisation) Transform technology and operations (example sub-dimension: Process digitization)	Stage 1 (bottom quartile): Digital passive Stage 2 (third quartile): Digital literate Stage 3 (second quartile): Digital performer Stage 4 (top quartile): Digital leader Alternative description of levels: DAI score of 67 to 100 'champions' DAI score of 43 or less 'laggards'	Organisational data aggregated to the industry level	**A quantitative survey** The survey included 26 questions, scored on a scale from 1 to 4 (anchors were not specified). The survey was administered to senior executives/leaders in participating organisations. No further information is available on how the dimensions of digital maturity are measured.	In 2017, online survey with 1,300 companies in Europe and U.S. They reported the results for organisations in the Nordic region but noted that the industry mix of respondents in the Nordic region is different from other regions (e.g., technology, media and telecom companies, which tend to be more advanced with digitization – made up 30% of the respondents across Europe and North America, but only 17% in the Nordics). In 2018, 1,900 companies in Europe and U.S. were surveyed. They represented manufacturing, chemicals, technology, banking, telecommunications, consumer goods and retail, automotive, energy, health care, and the public sector.
Digital Business Global Executive Survey **https://sloanreview.mit.edu/projects/achieving-digital-maturity/**	Deloitte and MIT Sloan Management Review (Kane et al., 2017)	No dimensions were conceptualised. Digital maturity was measured with just a single question that asked respondent to rate how mature they perceived their organisation to be.	Early (rating 1-3) Developing (rating 4-6) Maturing (rating 7-10)	Organisational data aggregated to the industry level	**A quantitative survey** The survey was administered via one-on-one interviews with executives. Respondents were asked to rate their company on a scale from 1 to 10, against an "ideal organisation that is transformed by digital technologies and capabilities that improve processes, engage talent across the organisation, and drive new value-generating business models". However, several other questions in the (published) survey can be considered to reflect dimensions of digital maturity (e.g., leadership with the vision to lead a digital strategy; cultivates a digital culture that strives for risk-taking, experimentation, agility and collaboration).	Annual surveys titled 'Digital Business Global Executive Survey' have been conducted from 2010 to 2016 (in 2016, <3% (n=45) of participants came from Agriculture and Agribusiness; the majority came from IT and technology; Professional services; and Education). The survey has been conducted across the globe in hundreds of countries and several industries (e.g., in 2016, 117 countries and 29 industries, with more than 3,500 respondents). An online interactive tool has been developed to allow people to view and interact with the results (e.g., by selecting an industry or region). https://sloanreview.mit.edu/2017-digital-business-interactive-tool/
Digital Maturity Dashboard	Capgemini & MIT Center for Digital Business	9 dimensions but no definitions provided (only question items provided). Business model transformation (e.g., item: We use digital	Numeric score for each dimension 1=very low 7=very high	Organisational data aggregated to the industry level	**A quantitative survey** The survey comprised 53 questions scored on a binary 'disagree' or 'agree' response scale. The survey was administered via interviews with senior executives (469 interviews from	In 2014, 15 different industries were assessed, though only a detailed report for Manufacturing is provided. Among the assessed organisations, 50 were associated with the

Name	Author	Dimensions of Digital Maturity	Stages/levels of Digital Maturity	Level of analysis	How assessed	Industry application
		technologies to increase the added value of our products and services) Operational excellence Customer experience Digital vision (e.g., item: Senior executives have a digital transformation vision that involves radical change) Governance Organisational engagement IT-business alignment (e.g., item: IT and business executives have a shared understanding of IT's role in our organisation) IT integration (e.g., item: Different units of the company use a common digital platform) Digital skills (e.g., item: We have the necessary skills in digital leadership to conduct digital initiatives)			391 companies in 30 countries). The questions used to assess digital maturity are published, however, it is not clear how they align to 4 of the 9 dimensions because different labels were used in the reporting of these results (e.g., 'Worker enablement' questions were reported on; however, it is not clear which of the 9 dimensions these questions relate to).	manufacturing industry (aerospace, automotive and industrial products).
Value-Centric Maturity Model **https://www.digitalmaturitybenchmark.com/**	KJR Pty Ltd in collaboration with QUT's Chair in Digital Economy and Isobar Australia	13 dimensions with definitions provided. Strategy (capability) Digital infrastructure and platforms (capability) Risk management (capability) Talent and skills (capability) Customer experience design (capability) Technology/business ecosystem design (capability) Vision (impact) Leadership (impact) Governance (impact) Innovation culture (impact) Value alignment (impact) Business agility (impact) Revenue resilience (impact)	Initiate (0-75 capability score, 0-75 impact score) Competent (76-150 capability score, 0-75 impact score) Purposeful (0-75 capability score, 76-150 impact score) Transformative (76-150 capability score, 76-150 impact score)	Organisation	**A quantitative survey** The survey comprised 3 to 10 questions per dimension. Questions were scored on a scale from 1 (strongly disagree) to 5 (strongly agree), with 3 (neutral) and a 'not applicable' option provided. Scores were added together to create an overall capability score and an overall impact score. These aggregated scores then reflected the 'stage' of overall digital maturity.	No information is available on the application of the tool; however, the questionnaire is available online for free usage, along with instructions on how to score the instrument.
Digital Maturity Assessment **https://digital.sa.gov.au/resources/topic/di**	SA Government	5 dimensions with definitions provided. Governance and leadership People and culture Capacity and capability	Minimal Informal and reactive Transitional Customer-driven Transformed	Organisation	**A quantitative survey** The survey presented behavioural descriptors from level 1 (minimal) to level 5 (transformed) for each dimension. Respondents then ticked the behavioural descriptors that they felt	No information is available on the application of the tool; however, the questionnaire is available online, along with instructions on how to score the instrument.

Name	Author	Dimensions of Digital Maturity	Stages/levels of Digital Maturity	Level of analysis	How assessed	Industry application
gital-government/digital-transformation-toolkit		Innovation Technology			applies to their organisation. Overall digital maturity was calculated by averaging scores across the 5 dimensions.	
Digitisation Index for Australia	Digital McKinsey	3 dimensions broken down into 37 metrics Digital assets Digital usage Digital labour	Not specified, yet colour-coded into relatively low or high digitisation	Industry	**Objective metrics** Objective metrics sourced from publicly-available big datasets at the industry level (sourced from ABS, DIBP, ASX300 annual reports, Facebook, Twitter, Appstore/iTunes, Google Play Store, LinkedIn, McKinsey analysis). Examples of objective metrics included: • number of job titles that include the words 'digital, 'data' or 'software' on LinkedIn as a share of the total number of jobs on LinkedIn, per ASX300 company; • share of businesses that use social media to collaborate with partners or other organisations; • share of businesses with internet access; • computer software net capital stock as a share of total net capital stock	In 2017, 37 objective indicators from big data sources were used to calculate a digitisation index for a range of industry sectors in Australia, including Agriculture. Agriculture had relatively low digitisation across all metrics. Further details on this model will be described in the Agriculture section in this report. McKinsey Global Institute has also applied the same digitisation index in the U.S. and Europe.
Australia's Digital Pulse	Deloitte Access Economics and Australian Computer Society (ACS)	4 dimensions broken down into 15 indicators Consumers ICT sector Businesses Workforce skills	Not specified	National	**Objective metrics** Objective metrics sourced from publicly-available (or custom-requested) information and/or big datasets sourced from ABS; data and reports from Australian Government departments; the OECD, WTO, the UN, and other research organisations; and LinkedIn. 'Consultations' with industry, academic and government experts also was included however, the methods and data derived were not specified. Examples of objective metrics included: • % households with internet access • % of exports that are ICT • % of graduates that are ICT university graduates	In 2015, 2016, 2017 and 2018, Australia's digital competitiveness was assessed and compared to other countries in the world.
Australia's Digital Readiness Index	Cisco and Gartner	7 dimensions Technology infrastructure Technology adoption Human capital Basic human needs Ease of doing business Business and government investment	Activate (lowest stage of digital readiness) Accelerate (moderate stage of digital readiness) Amplify (highest stage of digital readiness)	National	**Objective metrics** Objective metrics sourced from publicly-available information and/or big datasets. Examples of objective metrics included: • Fixed broadband subscriptions • Internet usage • Adult literacy rate	In 2018, Australia's digital readiness was assessed and compared to other countries in the world. Australia was ranked in the highest category of digital readiness. State-based assessments also were conducted, revealing state variability in digital readiness.

Name	Author	Dimensions of Digital Maturity	Stages/levels of Digital Maturity	Level of analysis	How assessed	Industry application
		Start-up environment			• Access to electricity • High-technology exports	The Digital Readiness Index has been applied to 118 countries globally.
Big Data and Analytics Maturity Model	Nott (2014) Skinner et al. (2017)	7 dimensions with definitions provided Strategy Data Analytics Culture Technology Training & SMEs	Five maturity levels Ad hoc Foundational Competitive Differentiating Breakaway	Industry (agriculture)	**Mixed methods (qualitative data and a quantitative survey)** The assessment was primarily qualitative, informed by observations and feedback from workshops with stakeholders (where some producers attended), desktop research and interviews with stakeholders. Additional insights were taken from a quantitative survey administered to 1,000 producers across 17 agricultural sectors.	In 2017, IBM's model was applied to develop a big data maturity model for Agriculture by Skinner and colleagues.
A patient-centred framework for evaluating digital maturity of health services	Flott et al. (2016)	4 dimensions with definitions provided Resources and ability Usage Interoperability Impact	None specified	Organisation (health)	The model has only been conceptualised, not operationalised. Thus, no details are provided on how digital maturity, according to this model, can be measured.	The model was designed for the health services industry, however has not been demonstrated.
Industry 4.0 Maturity Model	Schumacher, Erol & Sihn (2016)	9 dimensions, broken down into sub-dimensions (the number of sub-dimensions was not specified). No definitions were provided. Strategy (e.g., implementation of I40 roadmap) Leadership (e.g., Willingness of leaders) Customers (e.g., Utilisation of customer data) Products (e.g., Digitalisation of products) Operations (e.g., Decentralisation of processes) Culture (e.g., Knowledge sharing) People (e.g., ICT competences of employees) Governance (e.g., Labour regulations for I40) Technology (e.g., Existence of modern ICT)	Five maturity levels (reflecting the scores on the 1 to 5 likert scale for each item; and weighted, averaged score for each of the dimensions)	Organisation (manufacturing)	**A quantitative survey** The survey comprised 62 questions scored on a likert-scale from 1 (not implemented) to 5 (fully implemented). For example, to assess 'implementation of an Industry 4.0 roadmap' in the Strategy dimension, the question was "Do you use a roadmap for the planning of Industry 4.0 activities in your enterprise?". In calculating the overall score for each dimension, each item was weighted based on the importance rating averaged across 23 experts. A software tool was developed to present the maturity level for each item (on a 1 to 5 scale), as well as for the overall dimension (a weighted score). These results were presented graphically via radar charts.	A case study has been undertaken with an Austrian manufacturing enterprise. To ensure accuracy of results, this organisation was selected on the basis that it was already engaged in Industry 4.0 and therefore possessed basic knowledge/understanding of I40 concepts. The full set of survey questions are not provided in the publication (only examples). This model is generic; a more domain-specific model for Industry 4.0 maturity in automotive manufacturing companies is planned.
Digital Maturity Model	Valdez de Leon (2016)	7 dimensions with definitions provided. Strategy Organisation	Six maturity levels 0=not started 1=initiating 2=enabling	Organisation (telecomm)	The model has only been conceptualised, not operationalised. Thus, no details are provided on how digital maturity, according to this model, can be measured. However, like the SA	The model was designed for telecommunications service providers, however has not been demonstrated.

Name	Author	Dimensions of Digital Maturity	Stages/levels of Digital Maturity	Level of analysis	How assessed	Industry application
		Customer Ecosystem Operations Technology Innovation	3=integrating 4=optimising 5=pioneering		Government digital maturity model, the authors provide quite detailed behavioural descriptors for each maturity level therein. Thus, it may be possible for organisations to assess themselves using these behavioural descriptors.	Industry-specific modifications are advised to make the model fit for other industries (Valdez de Leon, 2016).
Digital Maturity Model	Deloitte and the TM Forum	5 dimensions broken down into 28 sub-dimensions. Definitions provided on the dimensions. Customer (example sub-dimension: Customer Engagement) Strategy (example sub-dimension: Brand management) Technology (example sub-dimension: Applications) Operations (example sub-dimension: Agile change management) Organisation & Culture (example sub-dimension: Leadership & Governance)	Not specified	Organisation (telecomm)	**A quantitative survey** The survey included 179 'individual criteria' on which digital maturity was assessed. No further details were provided on who was surveyed, how the dimensions of digital maturity were measured, or scored.	The model has received endorsement from several telecommunications organisations (e.g., Vodafone, BT, China Unicom, China Mobile) but it is unclear whether it has been applied in this industry.
Digital Maturity Benchmark	Deloitte	8 dimensions but no definitions provided. Strategy Innovation Experience Cyber security Digital channels & sales Openness of the bank Data & insights Digital marketing	Laggards Followers Average Leaders	Organisation (banking)	**A quantitative survey** The survey included 65 questions and was administered via one-on-interviews with bank executives in 7 participating banks. Detailed information was not provided on how the dimensions of digital maturity were measured, nor on how the levels of digital maturity were scored.	In 2017, applied to the banking industry in Belgium.

As can be observed, across the board, the digital maturity models were designed as descriptive tools in that they define the current states of digital maturity, identifying areas of relative strength and weakness as an organisation or industry seeks to achieve their desired 'level' of digital maturity. They are not prescriptive, which means that they do not serve the purpose of describing the best way to achieve the desired state of digital maturity; this is a separate activity that would require additional applied research (e.g., field studies that compare and evaluate the performance of different digital transformation interventions).

In the ensuing review of both the general digital maturity models and industry-specific research, we draw out key insights that will inform the development of our digital maturity model for agriculture.

2.1 General digital maturity models

Several general digital maturity models have been developed that can be used to compare the digital maturity status of organisations, industries and nations. The shaded entries in Table 1 are some representative examples of these more general models.

A review of these models reveals that digital maturity can either be assessed subjectively by surveying senior staff in organisations through questionnaire/interview, or objectively by referring to metrics available in big datasets such as ABARES, ABS data, LinkedIn data. The survey approach affords organisational and industry comparisons whereas the big-data approach yields industry and national comparisons. It is also noted that the survey approach may be considered more resource-intensive because it requires primary data collection, whereas the big-data approach uses secondary data that is often freely available. Nonetheless, either of these two approaches could be effectively used to assess digital maturity in agriculture, though it should be highlighted that where cross-sector comparisons (within agriculture) are required, the big-data approach would necessarily require datasets to be available for each sector of agriculture.

Unfortunately, in many instances, details of the model, measurement and analysis were lacking. This lack of information may be because some of the models and tools are propriety-owned and can only be accessed once purchased. The dimensions and sub-dimensions were only occasionally defined, and simply labelled and presented in pictorial form to depict the model's structure. Additionally, complete information on the survey questions and scoring key was typically missing from the models developed by consulting firms. This limited information makes it difficult to evaluate the construct validity and conceptual coverage of these models.

It was also observed that the specificity or precision of dimensions varied significantly across models. Some models included dimensions that were broad, encompassing a range of sub-dimensions. Whereas other models included dimensions that were conceptually narrower in focus. Table 2 provides an example of this observation. Here, we can see that Deloitte and the TM Forum's model's dimension for 'Organisation &

Table 5 Comparison of the 'Culture' dimension across three digital maturity models

	Deloitte & the TM Forum (for telecommunications)	South Australian Government	KJR
Dimension:	Organisation & Culture	People & Culture	Innovation culture
Definition:	Defining and developing an organisational culture with governance and talent processes to support progress along the digital maturity curve, and the flexibly (sic) to achieve growth and innovation objectives.	The organisation's culture, including customer focus, innovation, risk appetite and attention to managing change – especially staff roles.	Organisational culture is the set of shared assumptions that determines how an organisation perceives, thinks about, and reacts to, its environment. In digital organisations, it is necessary to create an innovative culture whereby the organisation can continually improve its offering to customers. For this to occur, risk taking should become a cultural norm within the organisation. This allows for greater innovation capacity as companies that are too risk averse often fail to take full advantage of opportunities that may transform the business.
Example questions:	None specified	A single behaviourally-anchored rating scale where multiple behaviours are described at each point, on a 1 to 5 scale. The anchors at the '5' point include: **all staff are digitally savvy and aware; having a defined 'digital team' becomes obsolete* **digital culture is embedded into overall corporate culture and constantly monitored, improved and refined* **feedback from customers and staff is encouraged, made public, and lessons learned are applied* **staff proactively generate and explore ways to improve digital service delivery and internal productivity via digital solutions*.	8 questions, rated on a 1=strongly disagree, 3=neutral, 5=strongly agree. Examples include: **In my organisation, everyone has a mandate to think creatively and innovate*. **My organisation takes a rigorous and systematic approach to innovation or change management*. **My organisation empowers staff to work autonomously as required, while providing an appropriate level of vision, guidance and coordination to maintain focus*. **My organisation conducts both small iterative experiments, and enterprise wide initiatives to realise innovation that has business impact*.
Sub-dimension:	Culture Leadership & Governance Organisational Design & Talent Management Workforce Enablement	None specified though the single measurement item suggests multiple sub-dimensions	None specified
Other dimensions in the model:	Customer Strategy Technology Operations	Governance and leadership Capacity and capability Innovation Technology	Vision Leadership Governance Value Alignment Business Agility Revenue Resilience Strategy Digital Infrastructure and Platforms Risk Management Talent and Skills Customer Experience Design Business Ecosystem Design

Culture' is broad and multidimensional, incorporating many sub-dimensions. Similarly, the South Australian Government model's dimension for 'People & Culture' is also multi-dimensional, although it is only measured through a single item (raising concerns about measurement error[1]). By comparison, KJR model's dimension for 'Innovation Culture' is narrow and unidimensional, measuring a single construct through the administration of several questions. Thus, there may be two approaches to designing a digital maturity model – to develop fewer broader dimensions that can be broken down into several sub-dimensions, or to develop several narrower dimensions that may not necessarily break down further into sub-dimensions.

Despite the variability across models and the lack of detailed information, a review of these more generalised digital maturity models has been useful in guiding our early thinking about how to conceptualise and measure a digital maturity model for agriculture. Our ensuing review of digital maturity in the agricultural context is expected to be more helpful in articulating the digital maturity dimensions that will be most appropriate to agriculture.

2.2 Industry-specific digital maturity models

2.2.1 Agriculture

There has been, so far, very limited work on digital maturity in the agricultural industry. A report ("A big data reference architecture for digital agriculture Australia") by Skinner et al. (2017) appears to be the most comprehensive effort to date, in relation to evaluating the state of digital maturity in agriculture. However, its focus was on evaluating the maturity of big data use specifically, as opposed to exploring digital maturity at a lower-level of analysis and across a range of dimensions beyond big data use. Additionally, as indicated in Table 1, McKinsey & Company's global assessment of digital maturity across Europe (McKinsey & Company, 2016), the U.S. (McKinsey & Company, 2015), and Australia (Digital/McKinsey, 2017) has developed a general Digitisation Index and applied to a broad range of industries including agriculture. This Digitisation Index is often referred to by industry stakeholders, when discussing the current state of digital maturity in the Australian agricultural industry. Both Skinner's and McKinsey's digital maturity models are discussed in greater detail below.

[1] By including multiple behavioural descriptors, the item invariably becomes a multidimensional measure. It is difficult for an individual to provide a valid (i.e., a response that reflects what the measure was intended to measure) and reliable response (i.e., a response that is consistent across time) to an item that is multidimensional. Best practice questionnaire design recommends the design of questionnaire items that precisely and consistently measure a single variable of interest (i.e., are unidimensional).

Big data maturity model

IBM's big data and analytics maturity model (Nott, 2014) has been applied in agriculture, to develop a 'big data reference architecture for digital agriculture in Australia', more simply known as a 'big data maturity model' (Skinner et al., 2017).

This big data maturity model includes seven dimensions, as discussed by Skinner and colleagues (2017):

- Strategy – The industry has developed and communicated strategies that enable them to use available data and apply analytics to innovative, improve their decision-making processes, maximise their value chain and open new market opportunities (p. 25).
- Data and Culture – Use of data to inform on-farm decision making is the base capability. The industry understands that data is a valuable asset (and comes from many sources) and supports producers to provide governed access to their data, sharing it with third parties where valuable to give it meaning and context. Industries promote data or information first approach to decision-making and offer producers diverse, targeted data analytics services aligned to their production processes in order to embed data into modern industry production practises (p. 25-26).
- Analytics – The industry makes data-driven decision-making pervasive throughout their value chains and this requires timely insight in context. (p. 26)
- Technology – The industry establishes architecture that supports the volume, variety, and velocity of big data. (p. 27)
- Governance – The industry has policies in place covering ownership, provenance, currency, data quality, foundational data and metadata, lifecycle management, security, privacy, and ethical use. (p. 27)
- Training & Small-to-Medium-Enterprises – Training staff and augmenting capability by identifying, evaluating and establishing trusted Small-to-Medium-Enterprises (SMEs) is essential for big data success. The industry recognises big data and data science as core competencies, builds business value, and invests in their people and partnerships to maximise the opportunities. (p. 27-28)

While this model comprises dimensions with the same labels (e.g., Strategy, Technology, Governance) used in some of the generalised models discussed above, it also differs in that it combines Data and Culture into a single pillar and includes some differently-labelled dimensions (e.g., Analytics, Training & Small-to-Medium-Enterprises). Culture would usually be positioned as a distinct dimension, else combined with 'People' (see the SA Government digital maturity assessment). However, we note that Skinner's assessment of the 'Data and Culture' pillar reported on Culture and Data separately, so it may be prudent to partition these dimensions from the outset when conceptualising the model. Training & Small-to-Medium-Enterprises may be akin to the variously labelled dimensions of Capability, Talent and Skills, although the

presence of SMEs appears to be unique to agriculture. Similarly, Analytics did not appear to be represented in previous general models; perhaps the closest representation would be data-driven marketing (in Boston Consulting Group's Digital Acceleration Index[2]) though this sub-dimension was not defined further, nor were questions provided, so it is difficult for us to conduct a true comparison.

The model also differs from the generalised models in that all dimensions are defined to reflect the unique context of big agricultural data. This suggests that while a more general, broad set of digital maturity dimensions can be applied to agriculture, the conceptualisation and operationalisation of these dimensions should reflect the uniqueness of agriculture.

Like previous general models, the 'big data maturity model' also used IBM's five stages or levels of maturity: ad hoc, foundational, competitive, differentiating and breakaway. The five levels of maturity were applied to each maturity dimension to create a 6 x 5 Evaluation Matrix and a brief behavioural description was provided for each level within each dimension (see pg. 29-31, Skinner et al., 2017). This provides confirmation that in the reporting of results, it will be important to establish thresholds to reflect different levels of digital maturity for each dimension.

Digitisation Index

Developed and applied in the U.S. and the European Union, McKinsey Global Institute's Industry Digitisation Index has also been used in Australia to assess and compare digital maturity across multiple industries, including agriculture (Digital McKinsey, 2017). This index is designed to only assess the maturity levels of digitisation in the industry and its business processes. As such, the index includes only three dimensions, and each of the dimensions is measured with several objective indicators or metrics:

- Digital assets – for example, share of business spending on computer systems, internet, and telecommunication, as well as the stock of ICT assets.
- Digital usage – for example, industry's use of digital ordering, digital marketing, and social technologies, as well as the adoption of digital supply chains, business processes and customer interactions.
- Digital labour – for example, the share of workers in each sector in digital occupations, as well as computer systems spending on a per-worker basis.

Paying note to the types of indicators used to measure these components, it is unsurprising then that, when assessed with this digitization model, high-technology, knowledge-intensive services industries (e.g.,

[2] Capgemini Consulting & MIT's model also included questions on analytics to contribute to an assessment of 'Customer understanding through digital channels' (an example question: "We use analytics to target marketing more effectively") (p. 11).

IMT, Financial, Professional and Administrative services) were rated as having relatively high digitisation, whereas asset-intensive industries (e.g., Agriculture, Mining, Construction and Utilities) were rated as having relatively poor digitisation. For high-technology, knowledge-intensive service industries – where digitisation is a central component of their business – it naturally follows that they would score highly on digital metrics (e.g., IMT companies would possess a great deal of ICT assets and would have employees in digitally-relevant occupations). By comparison, the main business of asset-intensive industries revolves around the provision of products, not digitisation, and as such, it naturally follows that they will not score as well on the digital metrics used in McKinsey's index.

While it may be virtually impossible for Agriculture to achieve a high digitisation score because of the nature of its business, it may still be informative to use some of these objective metrics to track changes over time, and to learn from other agribusinesses or similar industries who may be digitising at a faster pace. At present, producers may not specifically employ staff into digital roles, nor may they spend a lot on computer systems. However, both these aspects may improve over time as agribusinesses become more 'digitally savvy'. In designing the objective metrics that may be used, it is important to recognise that McKinsey's Digitisation Index relied on publicly-available big datasets rather than surveying individuals. If we choose to survey agribusinesses, we will need to carefully consider the impost in terms of asking agribusinesses to provide certain types of objective data (e.g., $ spending on computer systems, $ total capital expenditure), and ultimately design questions that are easier for agribusinesses to answer (e.g., Do you employ a staff member to handle the digital operations on your farm? Roughly, what percentage of your total operating expenditure goes towards digital devices).

Additional dimensions for agriculture

Combining the big data maturity assessment (Skinner et al., 2017) along with other insights from the literature (e.g., Cho, 2018; Zhang et al., 2017), we additionally propose the following key aspects as instrumental for advancing digital agriculture including:

- Telecommunication infrastructure – many farming technologies require external data connectivity, yet for most Australian farmers who rely on the mobile network, this connection is often not reliable or farm-wide (Cho, 2018; Zhang et al., 2017). Thus, at the most fundamental level, it would appear prudent to assess producer's satisfaction with internet connectivity.
- Digital/data literacy, capability and skills – for agribusinesses to derive the benefits from digital technologies and data, it is essential that they are equipped with (either personally, or externally-acquire) enough knowledge, skills and abilities to manage digital devices, and to interpret and act upon data and associated analytical insights.

- Data transparency and traceability – as part of the Findable, Accessible, Interoperable and Reusable (FAIR) datasets principles, to demonstrate compliance with legislative obligations for food safety, production methods, and biosecurity measures.
- Governance and best practices surrounding the management of data privacy and ownership – There also seems to be considerable ambiguity and uncertainty regarding the ownership of data collected on the farm (Cho, 2018). Many producers are very concerned about the privacy of their data and some may not completely understand the conditions of data ownership, which held producers back in sharing their farm data (Zhang et al., 2017). It may therefore be important to assess the level of confidence and trust that agribusinesses have in providing farm data to external third-party agencies, as well as their level of understanding regarding the terms and conditions surrounding data ownership and sharing.

We now review the literature on digital maturity in other industries, to derive further insights into additional dimensions that may be important to include in our assessment for Agriculture.

2.2.2 Health

With the rise of digital technologies to manage medical records and provide a higher quality health service, research has explored digital maturity in the health sector (Mettler & Pinto, 2018; Flott, Callahan, Darzi & Mayer, 2016). Pertinent to our purposes, a multidimensional framework for evaluating digital maturity in health has been proposed (Flott et al., 2016). In addition to emphasising the importance of deploying comprehensive evaluation methodologies (i.e., using both qualitative and quantitative research methods, and a wide range of stakeholders, to assess digital maturity), this framework outlines the following digital maturity metrics:

- Resources and ability – The resources available for a system, including the organisational readiness and individual abilities needed to use a new digital system correctly (e.g., organisations' existing technology, resources (finances, staff capacity, experience and willingness), cultural norms and leadership).
- Usage – The actual uptake of a system or the degree to which it is used by a range of people who need to input into it or otherwise access it (e.g., the volume of information transmitted, the duration and specific activity of users, or the number of login sessions).
- Interoperability – The capability of the organisation to communicate across services or other operating or Information Technology systems (i.e., the digital systems' ability to communicate across settings, including the harmonisation of terminology (known as semantic interoperability)).

- Impact – The impact it has in terms of both outcomes for patients and structure, process and finances (e.g., measuring the impact of the digital system in terms of public utility and cost-savings across stakeholders).

Of special note is that this framework moves beyond assessing resources and ability, to also assess the interoperability of systems. The interoperability of systems is deemed critical in health care, given multiple health care settings and stakeholders, and the importance of providing an integrated, patient-centric service (Flott et al., 2016). Interoperability is also considered important in Agriculture given the supply chain of production, multiple stakeholders (producers, retailers, distributors and manufacturers), and the importance of ensuring produce integrity via traceability. Thus, for our purposes, it will be important to assess the interoperability across digital systems both on-farm and across the supply chain. It may feature as a sub-dimension within the Technology dimension.

Additionally, this framework also includes a measure of the 'impact' of the digital system. While this dimension may be difficult to assess objectively in the agriculture context, it may still be possible to include questions that measure agribusinesses' perceptions of the benefits (e.g., return-on-investment) and how important digital technologies and data are to them, whether they are current users or not. More broadly, we could assess agribusinesses' perceptions of the technologies currently available on the market. With such an assessment, we could gauge overall sentiment towards digital technologies and data.

Interestingly, like Deloitte and the Sloan Management Review (Kane et al., 2017), other research examining digital maturity in the health care sector has assessed digital maturity by asking staff (through interviews and self-assessment survey) how sophisticated they perceived different information technology services to be (using a scale of 0=very low maturity to 4=very high maturity) (Mettler et al., 2018)[3]. Even though they also measured other variables that would be considered consistent with the digital maturity construct (e.g., perceived usage intensity (0=localised usage by single user/departments to 4=broad usage throughout the hospital), proportion of annual spending on hardware and software, operations and maintenance, and technology-related personnel development), their prime measure of digital maturity was the single, subjective rating. We remain cautious in following this approach however, as it is likely to be highly error-prone because people may hold different understandings of what 'maturity' means (given it is an abstract term). Thus, our preference will be to design concrete questions (reflecting facets of digital maturity) that may be interpreted similarly across people.

Other research in the health care setting has examined the maturity of a specific information technology: Picture Archiving and Communication Systems (PACS) (van de Wetering & Batenburg, 2009). Based on a

[3] This approach is like that used by Deloitte (Kane et al. 2017) where respondents were asked to "imagine an ideal organization transformed by digital technologies and capabilities that improve processes, engage talent across the organization, and drive new value-generating business models". They were then asked to rate their company against that ideal on a scale of 1 to 10.

qualitative meta-analytic review of 34 papers, this research presented a PACS maturity model that outlined five stages or levels of maturity, ranging from the basic and unstructured implementation and use of PACS, to a fully integrated and optimised use of PACS into the organisation to yield efficiencies. Importantly, the stages reflected increasing use of the technology across the supply chain to inform different decisions among a range of stakeholders. These aspects may also be relevant in the agriculture context as a range of on-farm digital technologies can inform the decisions and actions taken by stakeholders both on-farm and beyond the farm-gate, including end consumers. The adoption of technologies and usage of data for short-term decision-making only, may be considered a hallmark of early stages of digital maturity. Whereas, the use of data for more strategic decision-making (e.g., future projections; shared off the farm to assist community- or industry-wide decisions) may be considered a demonstration of high digital maturity. Thus, for our purposes, it will be important to assess the extent or intensity of usage of digital devices and data (including insights from data analytics) for decision-making on-farm.

2.2.3 Government

Digital government (e-Government or e-governance) – that is, the use of information and communication technologies in government agencies – is recognised as a way for government agencies to enhance their operations and ability to provide services to citizens and other external users (e.g., businesses, other government agencies). A plethora of e-government maturity models have been developed (Andersen, 2006; Layne & Lee, 2001; Shahkooh, Saghafi & Abdollahi, 2008). Interestingly, e-government models tend to be conceptualised as stages-of-change models, and the underlying dimensions of digital maturity appear to be given less attention. These models focus on describing technological objects in terms of technology type and adoption (such as use of bulletin boards versus chat rooms) or behaviour in terms of use of the technology and data throughout the organisation, rather than assessing broader organisational aspects or characteristics of digital maturity. Consistent with other digital maturity models, technology and data usage are likely to be important components of digital maturity in agriculture.

Not surprisingly, and like that raised in the health domain, interoperability has been identified as critically important for e-Government (Chen, 2007; Gottschalk, 2009). Gottschalk (2009) has even developed a maturity model specifically for e-Government interoperability, which describes different levels or facets of interoperability – computer interoperability (hardware and software communicating with each other), process interoperability (work processes are aligned), knowledge interoperability (knowledge is shared); value interoperability (value is created along a chain), and goal interoperability (organisations share the same goal). Additionally, in achieving the highest level of e-government maturity where data is mobile, shared and integrated, it is likely that concerns about data privacy may surface, especially where the data is personally identifiable (Chen, 2007; Gottschalk, 2009). As discussed in the earlier section on Agriculture, the same data privacy concerns resonate in Agriculture.

2.2.4 Manufacturing

Manufacturing is another industry that is continuing to face digital disruption as it seeks to digitally integrate manufacturing processes, and use new technologies (e.g., automation and intelligent systems) to increase efficiencies (Capgemini Consulting and MIT, 2014; Schumacher, Erol & Sihn, 2016). Extending other technology-dominated maturity models, a comprehensive digital maturity model and accompanying questionnaire tool (62-item) for assessing digital maturity in manufacturing enterprises has been created (Schumacher et al., 2016). While the questionnaire items are unpublished, it describes 9 dimensions of digital maturity (Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance and Technology).

Capgemini Consulting, in collaboration with the MIT Center for Digital Business (2014) also presents 9 dimensions of digital maturity (which apply not only to manufacturing but other industries too), which largely correspond to Schumacher's dimensions (i.e., IT-business alignment, Digital vision, Customer experience, Business model transformation, Operational excellence, Organisational engagement, Digital skills, Governance and IT integration). They also publish a full set of questions; however, it is not clear how the responses map onto 4 of the 9 dimensions as different terms were used in the reporting of results.

Both Schumacher et al. and Capgemini presented the digital maturity assessment in a visual format, using radar charts (see Figure 1 and Figure 2). As can be seen, the average scores for each dimension are simply plotted. Schumacher and colleagues additionally charted the results for the sub-dimensions (which in this case, are the raw scores for individual items). Previous digital maturity models have presented % agreement (presumably combining '4' and '5' scores on a 5-point agreement scale) (e.g., Kane et al., 2017), or summed scores to yield an overall digital maturity index (e.g., Boston Consulting Group's Digital Acceleration Index). Reflecting on these previous presentations of results, we propose presenting the digital maturity stage for each dimension using a radar chart. In the next phase of this project, we will present further detail on the presentation of results.

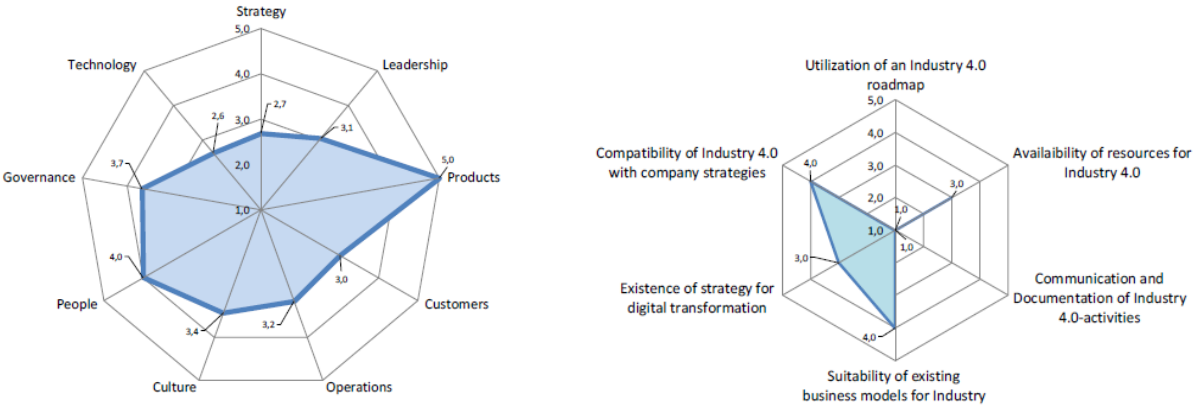

Figure 2 Radar charts presenting the dimensions of digital maturity, and the sub-dimensions of Strategy (Schumacher, 2016, p. 165)

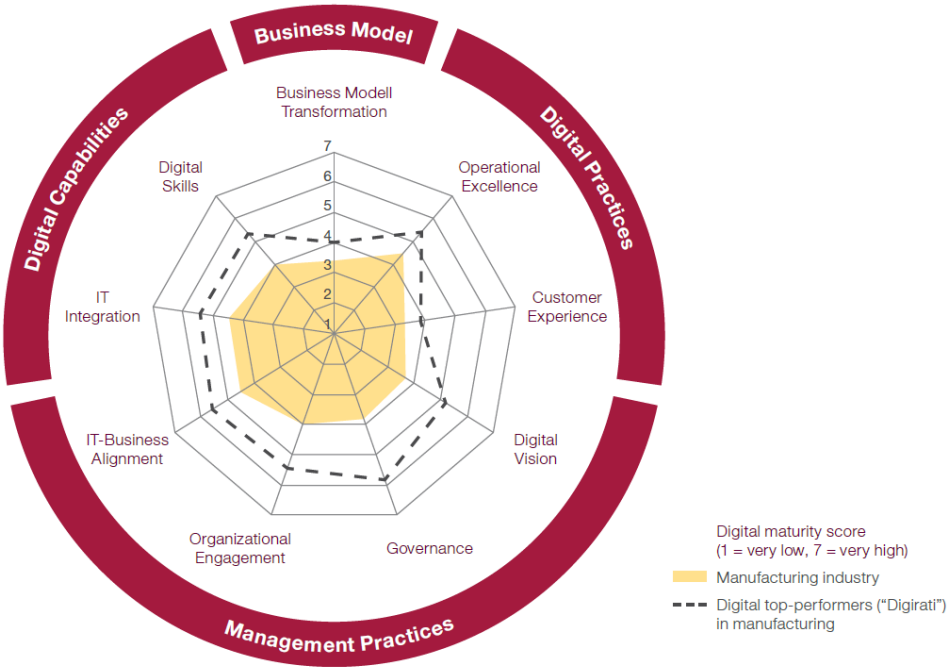

Figure 3 Radar chart presenting the dimensions of digital maturity in manufacturing (Capgemini & MIT, 2014, p. 5)

2.2.5 Telecommunications

The telecommunications service provider industry has, and continues to, transform from a provider of traditional communication services (e.g., telephone, SMS) to providers of digital services. A model of digital maturity for telecommunications service providers has been developed, which corresponds well to the general digital maturity models previously described (Valdez de Leon, 2016), including Deloitte and the TM Forum's model that has received endorsement from several telecommunication organisations. Seven dimensions were developed (Strategy, Organization, Customer, Ecosystem, Operations, Technology and Innovation), with six maturity levels in each dimension (Not started, Initiating, Enabling, Integrating, Optimising and Pioneering). No sub-dimensions were included however, which means that some of the dimensions are broad and multi-dimensional:

- Strategy: Representing the vision, governance, planning, and management processes that will support the implementation of the digital strategy
- Organisation: Characterising the changes in communications, culture, structure, training, and knowledge management within the organisation that will enable it to become a digital player
- Customer: Focusing on customer participation and empowerment, as well as new benefits created in customer experience through digital transformation of customer journeys
- Technology: Representing the capabilities that enable effective technology planning, deployment, and integration to support the digital business
- Operations: Focusing on the capabilities that support the service provision. Increased maturity within this dimension demonstrates a more digitised, automated and flexible operation

- Ecosystem: Signifying partner ecosystem development and sustenance as a key element for a digital business
- Innovation: Focusing on the capabilities that enable more flexible and agile ways of working that will form the basis for an effective digital business

The model is conceptualised through a detailed description of the characteristics of a business in each of the levels across the dimensions (see Figure 3). However, the supporting measurement approach to this conceptual model was not presented.

5. Technology
This dimension is focused on the capabilities that enable an effective technology planning, deployment, integration, and use to support the digital business.

Level 1 - Initiating	**The organization has decided to move toward a digital business and is taking initial steps in that direction.**
T1.1	A digital-specific, IT architecture is being developed.
T1.2	Efforts to define required transformation of IT architecture have been started.
T1.3	Some initial pilots are planned to test new digital tools and platforms.
Level 2 - Enabling	**The organization is implementing initiatives within the dimension that will form the foundation of its digital business.**
T2.1	A digital-specific IT architecture has been defined and changes to enterprise IT are ongoing to align it to target architecture. Tactical IT investment plans are aligned to target architecture.
T2.2	Platforms are being deployed to support digital services (e.g., an Internet of Things, or IoT, platform).
T2.3	An integral API and security strategy for supporting third-party services has been defined.
T2.4	Support systems are being implemented to support digital services (e.g., flexible charging and billing).
T2.5	There is a process to evaluate IT investments based on their alignment to the digital strategy of the organization.
Level 3 - Integrating	**The organization's initiatives are being integrated across the organization to support end-to-end capabilities.**
T3.1	Digital enterprise IT architecture has been largely implemented, including consolidation of stove-pipe systems into platforms for support of omni-channel and third-party services.
T3.2	Third-party services are being integrated and supported by digital enterprise IT architecture and related tools.
T3.3	Processes across the organization (e.g., customer support, partner onboarding) are aligned to digital IT architecture.
T3.4	Analytics technologies are being implemented to facilitate data collection and sharing across functions.
Level 4 - Optimizing	**The organization's digital initiatives within the dimension are being fine-tuned and used to further increase overall performance.**
T4.1	End-to-end processes supporting digital services are being optimized by leveraging the digital enterprise IT architecture.
T4.2	Integration tools are deployed to reduce time and costs of integration of third-party services.
T4.3	Digital IT architecture supports business agility through flexible tools and supporting processes.
T4.4	Analytics technologies are being used for optimization of services and processes.
T4.5	Automation of processes using real-time data processing is being used for proactive decision making across the organization.
Level 5 - Pioneering	**The organization is breaking new ground and advancing the state of the practice within the dimension.**
T5.1	Technologies such as advanced data analytics underpin innovation processes across the organization, from new service development through to service assurance to customer support.
T5.2	Automation throughout the organization drives superior performance (e.g., speed, reliability, ARPU, NPS) compared to industry peers.
T5.3	Tools using technology such as machine learning are implemented and used across the organization (and even to ecosystem partners) for predictive activities (e.g., service reliability, user consumption trends) that support digital business innovation.

Figure 4 Characteristics of the technology dimension within the digital maturity model for telecommunication service providers (Valdez de Leon, 2016, p. 30).

3 Proposed pillars of a digital maturity index for Agriculture

3.1 Proposed pillars of a digital maturity index for agriculture

Considering the general and industry-specific digital maturity models and frameworks, we propose the following pillars for a digital maturity index for agriculture:

- Strategy & Culture
- Technology
- Data & Analytics
- Capability
- Data Rules

In selecting these pillars, we drew heavily on Skinner and colleague's (2017) big data maturity model because it has already received some confirmation on its suitability for agriculture, and it comprises dimensions that were commonly found in other models. In the next phase of the project, we will define these pillars and develop the associated assessment tool.

3.2 Proposed stages of digital maturity

In addition to articulating the dimensions of digital maturity, many models outlined various stages or categories of digital maturity. For example, Boston Consulting Group's (BCG) Digital Acceleration Index involved processing survey responses from executives representing many companies in Europe and the United States. These responses were then compared against each other and companies were grouped into quartile ranges such that the bottom quartile was considered 'digital passive', the next quartile 'digital literate', the second top quartile 'digital performer', and the top quartile 'digital leader'. This approach is on a relative rather than absolute scale. That is, the category/stage an individual company falls into, depends on how their score compares to other companies, rather than on what score they absolutely achieved in relation to what an ideal digital maturity is like.

More recently, BCG calculated digital maturity in an absolute way by aggregating raw survey scores (and standardising to a 100-point scale). Those companies with an overall Digital Acceleration Index of 67 to 100 were labelled 'champions', while those companies with a DAI of 43 or less were labelled 'laggards'. Similarly, KJR Pty Ltd also calculated digital maturity in an absolute way, although their approach differed slightly in that they used a two-dimensional matrix yielding 4 'states' of digital maturity (rather than using a single linear scale to reflect overall digital maturity).

We argue that an overall digital maturity score can be somewhat misleading because it averages across several dimensions of digital maturity, reducing conceptual clarity, and classifying producers with entirely different digital maturity characteristics as having the same digital maturity overall. Thus, we would suggest that results be presented at the dimension-level. Certainly, we found that many of the models did just this – they presented scores for each dimension, ultimately reflecting the 'stage' of digital maturity for each dimension (e.g., Capgemini Consulting & MIT, 2014; Schumacher et al., 2016; Skinner et al., 2017; Valdez de Leon, 2016). Thus, we too propose presenting the averaged results at the pillar-level. In the next phase of the research, we will provide detail on the stages of digital maturity for each pillar.

3.3 Next steps

In closing, the next step of the project will be to develop the assessment tool to support the digital maturity index as defined in this report. In addition to developing the metrics, we will also develop the scoring method and procedures to produce the 'stage' results for each dimension of digital maturity. The assessment tool will be programmed into an online platform ready for use by agribusinesses.

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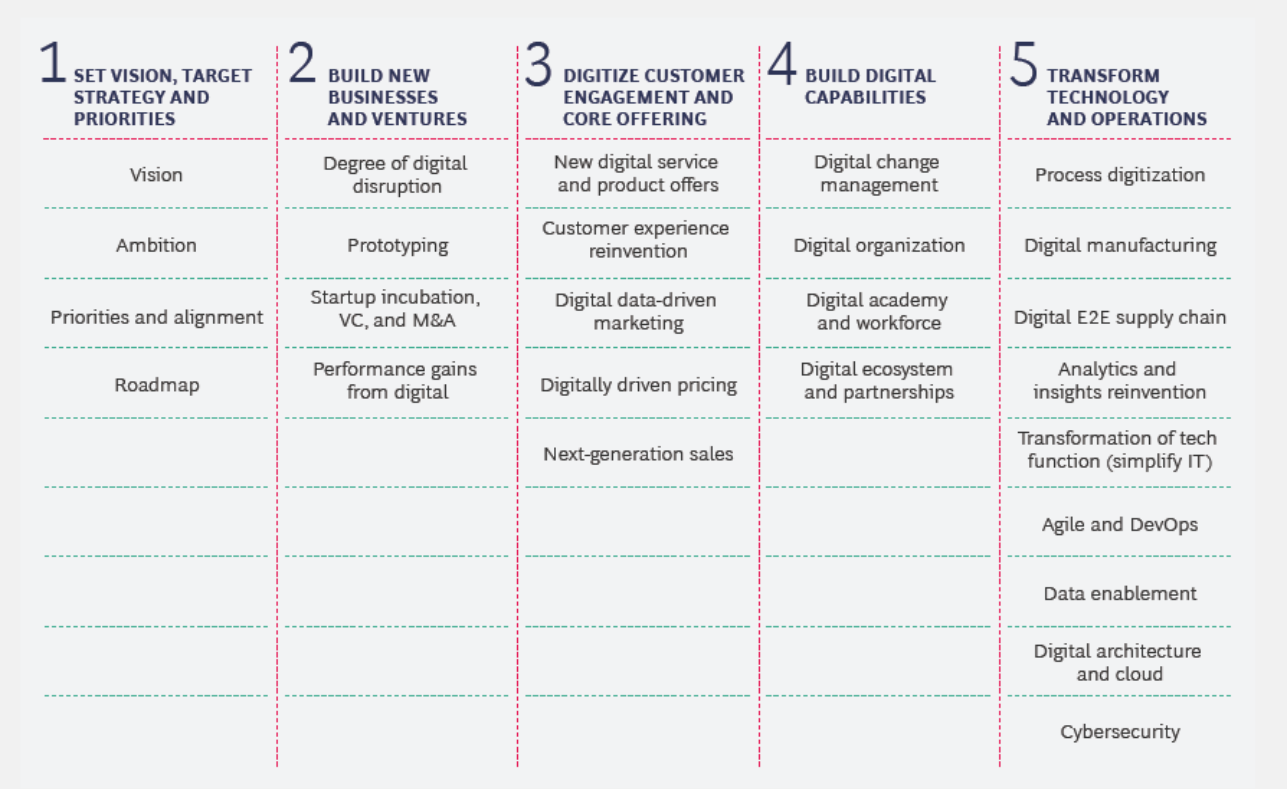
Appendix: Digital maturity models

Boston Consulting Group's Digital Acceleration Index

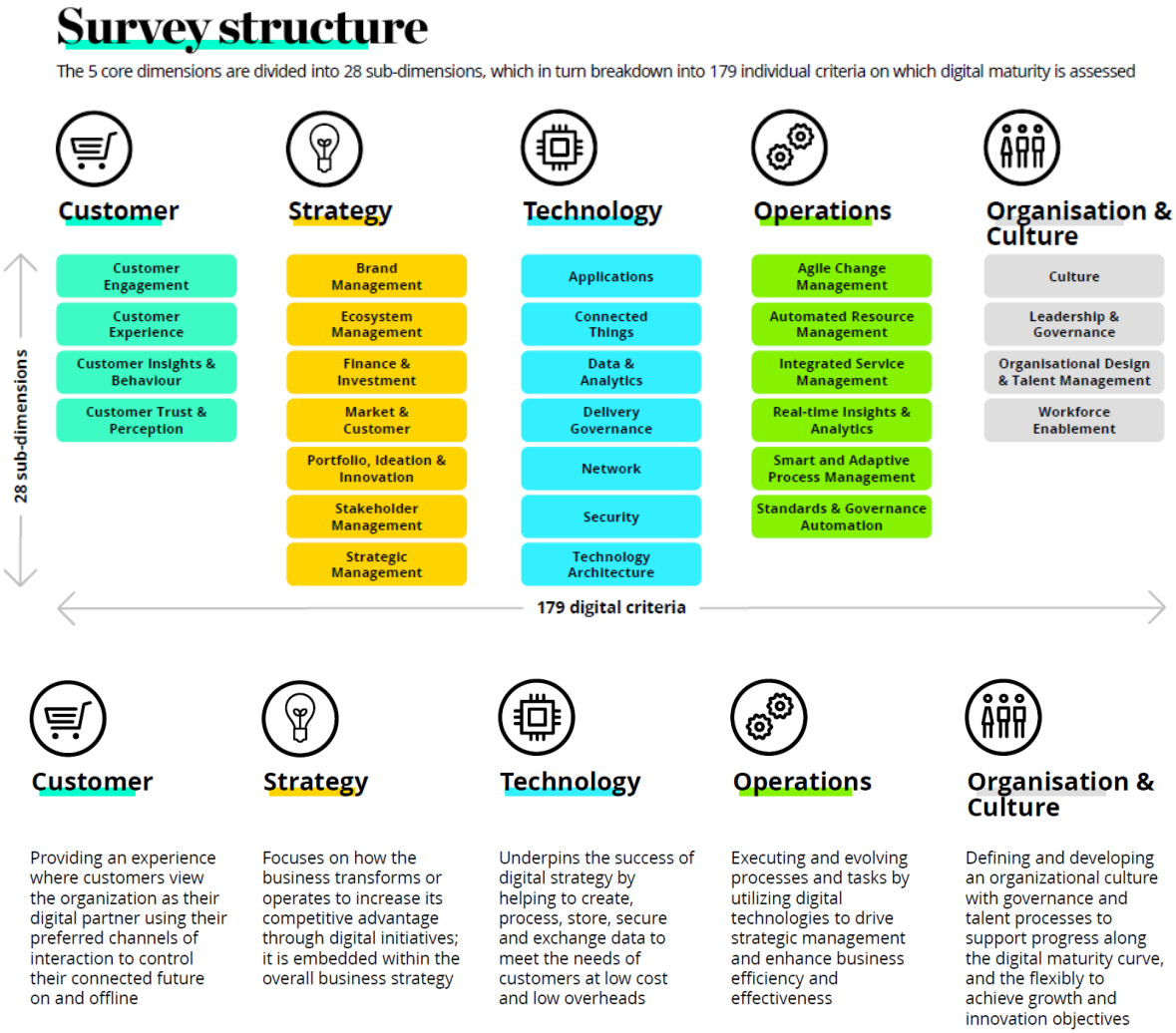


1 SET VISION, TARGET STRATEGY AND PRIORITIES	2 BUILD NEW BUSINESSES AND VENTURES	3 DIGITIZE CUSTOMER ENGAGEMENT AND CORE OFFERING	4 BUILD DIGITAL CAPABILITIES	5 TRANSFORM TECHNOLOGY AND OPERATIONS
Vision	Degree of digital disruption	New digital service and product offers	Digital change management	Process digitization
Ambition	Prototyping	Customer experience reinvention	Digital organization	Digital manufacturing
Priorities and alignment	Startup incubation, VC, and M&A	Digital data-driven marketing	Digital academy and workforce	Digital E2E supply chain
Roadmap	Performance gains from digital	Digitally driven pricing	Digital ecosystem and partnerships	Analytics and insights reinvention
		Next-generation sales		Transformation of tech function (simplify IT)
				Agile and DevOps
				Data enablement
				Digital architecture and cloud
				Cybersecurity

Source:

Kirvela, S., Heikkila, T., & Lind, F. (2017). Bigger, bolder, and faster. The digital agenda for Nordic companies, The Boston Consulting Group, pg. 9.

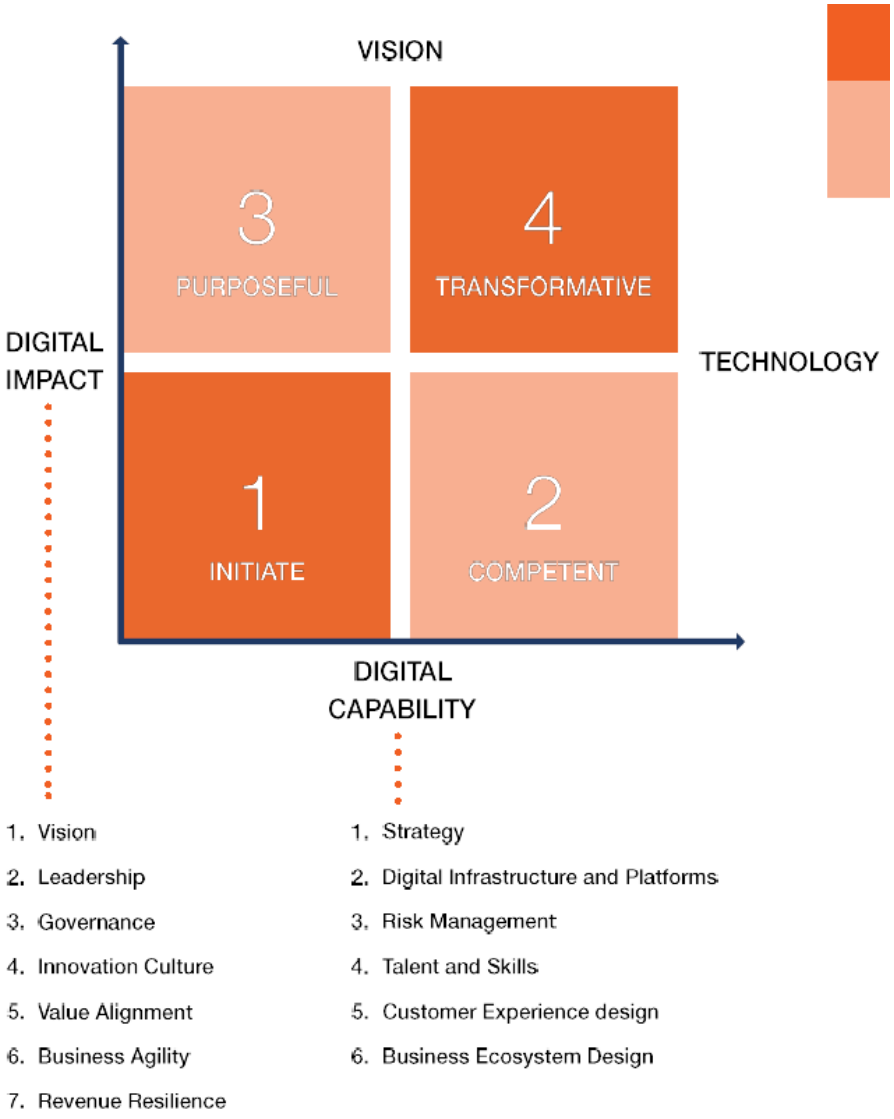
Deloitte’s and the TM Forum’s Digital Maturity Model



Source:

Deloitte (2018). Digital maturity model: Achieving digital maturity to drive growth. https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Technology-Media-Telecommunications/deloitte-digital-maturity-model.pdf

KJR Pty Ltd's Value-centric Digital Maturity Model



Source:

Shahiduzzaman, M., Kowalkiewicz, M., Barrett, R., & McNaughton, M. (2017). Digital business: Towards a value-centric maturity model. Part A. https://dxjtypzgmldtm.cloudfront.net/wp-content/uploads/2018/11/DIGITAL-MATURITY-MODEL-PART-A.pdf

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Schumacher's Maturity Model for Manufacturing

Table 2. Dimensions and maturity items of Industry 4.0 Maturity Model.

Dimension	Exemplary maturity item
Strategy	Implementation I40 roadmap, Available resources for realization, Adaption of business models, …
Leadership	Willingness of leaders, Management competences and methods, Existence of central coordination for I40, …
Customers	Utilization of customer data, Digitalization of sales/services, Costumer's Digital media competence, …
Products	Individualization of products, Digitalization of products, Product integration into other systems, …
Operations	Decentralization of processes, Modelling and simulation, Interdisciplinary, interdepartmental collaboration, …
Culture	Knowledge sharing, Open-innovation and cross company collaboration, Value of ICT in company, …
People	ICT competences of employees, openness of employees to new technology, autonomy of employees, …
Governance	Labour regulations for I40, Suitability of technological standards, Protection of intellectual property, …
Technology	Existence of modern ICT, Utilization of mobile devices, Utilization of machine-to-machine communication, …

I40…Industry 4.0, ICT…Information and Comm. Technology

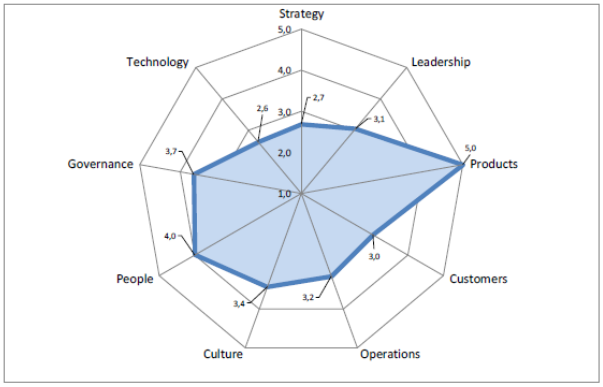


Figure 2: Radar chart visualizing Industry 4.0 maturity in nine dimensions.

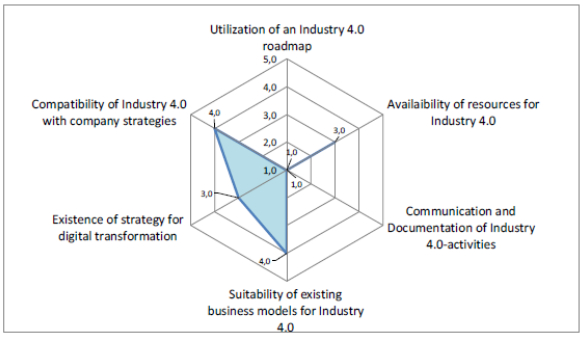
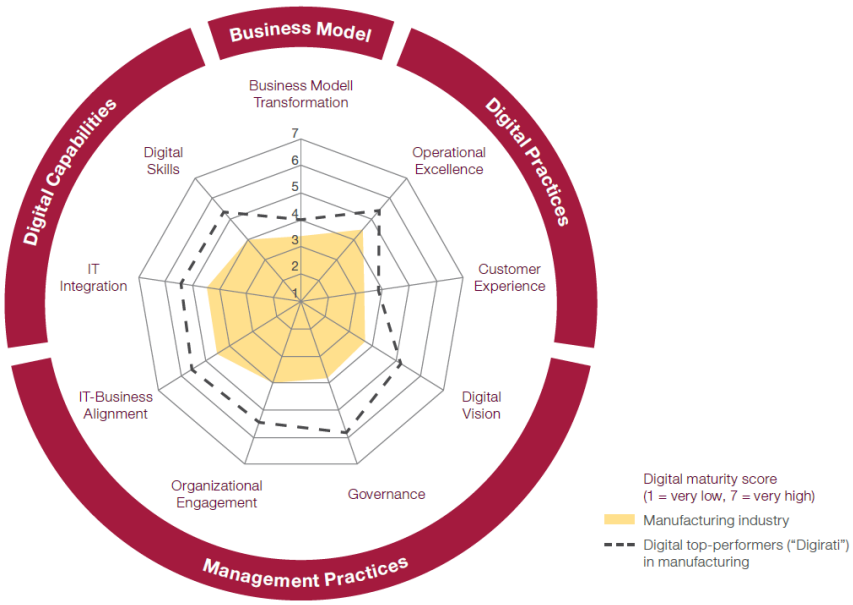


Figure 3: Detailed results for dimension Strategy.

Source:

Schumacher, A., Erol, S., & Sihn, W. (2016). A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia CIRP, 52,* 161-166.

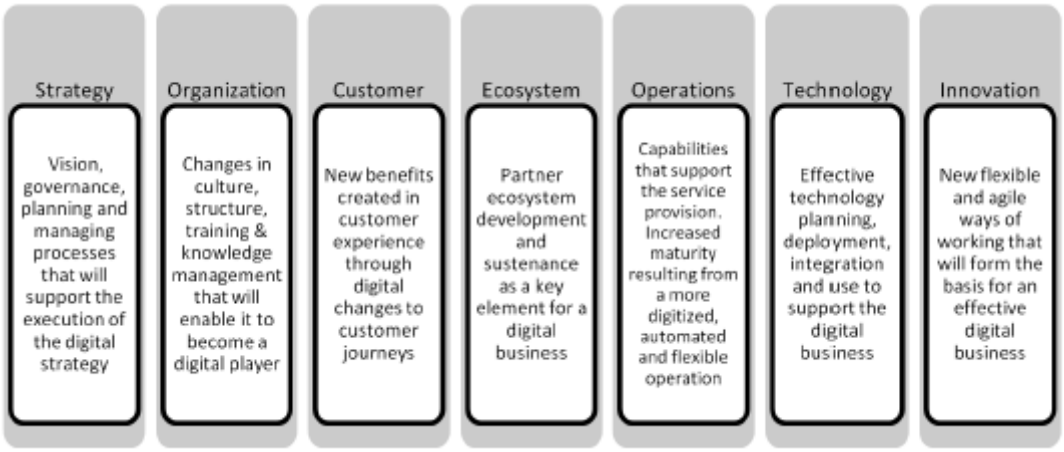
Capgemini Consulting & MIT's Digital Maturity Dashboard



Source:

Capgemni Consulting (2014). Digitizing Manufacturing: Ready, Set, Go! Manufacturing at the verge of a new industrial era. Report available at: https://www.capgemini.com/consulting-de/wp-content/uploads/sites/32/2017/08/digitizing-manufacturing_0.pdf

Valdez de Leon's digital maturity model for telecommunications service providers



Source:

Valdez de Leon, O. (2016). A digital maturity model for telecommunications service providers. *Technology Innovation Management Review, 6(8),* 19-32.

McKinsey Global Institute's Digitisation Index for Australia

Australian Digitisation Index is comprised of 37 metrics, across Digital Assets, Usage, and Labour

		Metric	Description
Assets	Digital financing	Replace hardware	• Share of businesses for which replacement of IT hardware is reason for financing
		Upgrade hardware or software	• Share of businesses for which upgrade of IT hardware or software is reason for financing
		New hardware or software	• Share of businesses for which purchase of additional hardware or software is reason for financing
	Digital spending	Computer systems share of all spending	• Computer systems industry input uses as a share of total input uses
		Internet (including telecommunications) spending	• Internet industry and telecommunications input uses as a share of total input uses
	Digital assets stock	Computer software net capital stock	• Computer software net capital stock as a share of total net capital stock
Usage	Transactions	Enterprises receiving orders online	• Businesses that receive orders via the internet
		Enterprises placing orders online	• Businesses that place orders via the internet
	Digital supply chain	Share of suppliers' business systems that are automated	• Share of suppliers' business systems that are automated
		Customer systems automation	• Share of customers' business systems that are automated
		Reordering replacement supplies automation	• Share of reordering replacement supplies that are automated
		Invoicing and payment automation	• Share of invoicing and payment that are automated
		Production or service operations automation	• Share of production or service operations that are automated
		Logistics automation	• Share of logistics (including electronic deliver) that are automated
		Marketing operations automation	• Share of marketing operations that are automated
	Customer service interactions	Businesses with internet access	• Share of businesses with internet access
		Businesses with web presence	• Share of businesses with web presence
		Businesses with social media presence	• Share of businesses with social media presence
		Businesses with social media presence	• Number of Facebook and Twitter posts per ASX300 company
		Use of social media for marketing	• Share of businesses that use social media to develop company image or market products
		Use of social media for customer communications	• Share of businesses that use social media to communicate with customers
		Use of social media for product development	• Share of businesses that use social media to involve customers in development or innovation of products
		Use of social media for collaboration with partners	• Share of businesses that use social media to collaborate with partners or other organisations
	Process	IT use in accounting processes	• Extent of IT use in accounting processes
		IT use in production processes	• Extent of IT use in production processes
		IT use in invoicing processes	• Extent of IT use in invoicing processes
		IT use in stock control processes	• Extent of IT use in stock control processes
		IT use in business planning processes	• tent of IT use in business planning processes
		App use for front-end processes	• Number of iTunes and Google Play apps per ASX300 company
	Strategy and innovation	R&D expenditure	• R&D expenditure as a share of total investment
		VC funding	• VC funding as a share of total investment
		Use of 'digital' in annual reports	• Number of times the word 'digital' appears per page in the annual report of each ASX300 company
Labour	Digitisation of work	Digital jobs as share of total jobs	• Number of job titles that include the words 'digital', 'data' or 'software' on LinkedIn as a share of the total number of jobs on LinkedIn, per ASX300 company
		Ability of staff to work from home	• Share of employees given the ability to work from home by their employers
	Digital spend per worker	Computer systems spending per worker	• Computer systems industry input uses per employee
	Digital talent	Social media recruitment	• Share of businesses that use social media for recruitment
		Digital 457 visa jobs	• Share of 457 visas granted for digitally relevant occupations

Source:

Blackburn et al. (2017). Digital Australia: Seizing the opportunity from the Fourth Industrial Revolution, Digital McKinsey, pg. 17.

McKinsey Global Institute's Digitisation Index for Europe

Metrics included in the MGI Industry Digitisation Index

		Metric	Description
Assets	Digital spending	Hardware spending	Share of total expenditures spent on ICT hardware (e.g., computers, servers)
		Software and IT services spending	Share of total expenditures spent on software and IT services (e.g., enterprise resource planning software)
		Telecommunications spending	Share of total expenditures spent on telecommunications (e.g., broadband access, mobile data services)
	Digital assets stock	Hardware assets	Share of total assets made up of ICT hardware (e.g., computers, servers)
		Software assets	Share of total assets made up of software (e.g., purchased software licenses)
Usage	Transactions	Enterprises selling online	Annual sales realised via any computer networks; computer networks include websites, EDI-type systems, and other means of electronic data transfer (excluding e-mails)
		Enterprises purchasing online	Percentage of companies doing at least 1% of their purchases via any computer networks; computer networks include websites, EDI-type systems, and other means of electronic data transfer (excluding e-mails)
	Interactions between firms, customers, and suppliers	Digital supply chain	Enterprises sending/receiving all type of information on the supply chain (e.g., inventory levels, production plans, forecasts, progress of delivery) via computer networks or via websites
		Social media use	Enterprises using two or more of the following social media: social networks, enterprise's blog or microblog, multimedia content sharing websites, wiki-based knowledge-sharing tools
		Companies with ICT very integrated into daily activities	Composite score based on McKinsey's 2015 survey on the digital capabilities of firms in Europe and the United States
		Companies with benefits from external customer-related tools	
		Companies with benefits from using social tools to work with partners	
		Companies where at least half of business is digital in nature	
	Processes	Enterprise Resource Planning use	Enterprises that have an ERP-enterprise resource planning software package, which they use to share information between different functional areas (e.g., accounting, planning, production, marketing)
		Customer Relationship Management use	Enterprises that use a CRM, i.e., any software application used for the analysis of information about clients for marketing purposes
Labour	Digital spending	Hardware spending on workers	ICT hardware (e.g., computers, servers) expenditures per full-time-equivalent employee (FTE)
		Software and IT services spending per worker	Software (e.g., enterprise software licenses) and IT services expenditures per FTE
		Telecommunications spending per worker	Telecommunications (e.g., broadband access, mobile data services) expenditures per FTE
	Digital capital deepening	Hardware assets per worker	ICT hardware assets (e.g., servers, computers) per FTE
		Software assets per worker	Software assets (e.g., workers software licenses) per FTE
	Digitisation of work	Share of jobs that are digital	Digital jobs (e.g., computer and information systems managers, web designers, social media community managers, database administrators, big data scientists) as a share of total jobs

SOURCE: McKinsey Global Institute analysis

Source:

Bughin, J., Hazan, E., Labaye, E., Manyika, J., Dahlström, P., Ramaswamy, S., & de Billy, C. C. (2016). Digital Europe: Pushing the frontier, capturing the benefits. McKinsey Global Institute, p. 9.

McKinsey Global Institute's Digitisation Index for the U.S.

Metrics included in the MGI Industry Digitization Index

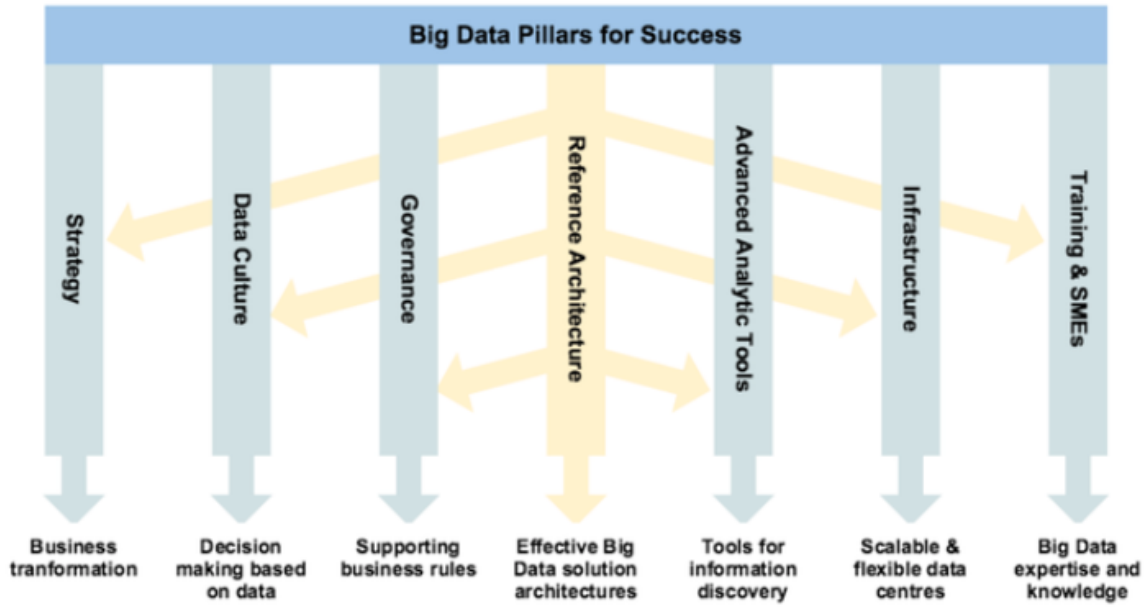
	Metric	Description
Assets		
Digital spending	Hardware spending	Share of total expenditures spent on ICT hardware (e.g., computers, servers)
	Software spending	Share of total expenditures spent on software (e.g., enterprise resource planning [ERP] software)
	Telecommunications spending	Share of total expenditures spent on telecommunications (e.g., broadband access, mobile data services)
	IT services spending	Share of total expenditures spent on IT services (e.g., IT consulting, IT architecture and implementation)
Digital asset stock	Hardware assets	Share of total assets made up of ICT hardware (e.g., computers, servers)
	Software assets	Share of total assets made up of software (e.g., purchased software licenses)
	Connected equipment	Share of equipment embedded with digital connections (e.g., oil rigs outfitted to transmit data on yield)
	Data storage	Data stored per firm, measured in terabytes, for firms with at least 1,000 employees
Usage		
Trans-actions	Digital transactions	Share of payments and transfers, both from consumers to businesses (C2B) and from businesses to other businesses (B2B) made through digital means (e.g., payments via ACH or wire)
Interactions between firms, customers, and suppliers	Digital external communications	Composite score based on share of firms reporting benefits from using social technologies to interface with customers and share of firms reporting benefits from using social technologies to work with partners
	Digital customer service	Composite score based on average number of customer service chats per month and share of total contact center calls routed by automated systems, i.e., integrated voice response (IVR) or automated speech recognition (ASR) technology
Business processes conducted internally	Digitized back-office processes	Composite score based on adoption of enterprise resource planning (ERP) software (e.g., SAP, Oracle) across the industry, and share of firms reporting that technology is very integrated into employees' daily activities
	Digitized front-office processes	Composite score based on adoption of customer relationship management (CRM) software (e.g., Salesforce.com) across the industry and digital marketing (e.g., email, banner and search engine advertisements) expenditures, as an estimated share of total marketing expenditures
	Product development software intensity	Intensity of software usage in product development process (e.g., for computer-assisted design)
Market making	Digitally enabled markets	Extent to which digital platforms are being used to connect supply with demand, calibrated using the relative size of digital bid-ask or auction-based markets (in terms of users, transactions, and/or revenues)
Labor		
Digital spending	Hardware spending on workers	ICT hardware (e.g., computers, servers) expenditures per full-time-equivalent employee (FTE)
	Software spending per worker	Software (e.g., enterprise software licenses) expenditures per FTE
	Telecommunications spending per worker	Telecommunications (e.g., broadband access, mobile data services) expenditures per FTE
	IT services spending per worker	IT services (e.g., IT consulting, IT architecture and implementation) expenditures per FTE
Digital capital deepening	Hardware assets per worker	ICT hardware assets (e.g., servers, computers) per FTE
	Software assets per worker	Software assets (e.g., worker software licenses) per FTE
Digitization of work	Share of tasks that are digital	Time-weighted share of worker tasks involving digital tools or processes (e.g., tasks requiring workers to input information via tablet, conduct online research, or perform analyses with spreadsheet software). Based on a search for digital keywords (e.g., data, computer, software) in a publicly available database of worker tasks
	Share of jobs that are digital	Digital jobs (e.g., computer and information systems managers, hardware engineers, telecommunications equipment installers and repairers) as a share of total jobs

SOURCE: McKinsey Global Institute analysis

Source:

Manyika, J., Ramaswamy, S., Khanna, S., Sarrazin, H., Pinkus, G., Sethupathy, G., & Yaffe, A. (2015). Digital America: A tale of the haves and have-mores. McKinsey Global Institute, p.30.

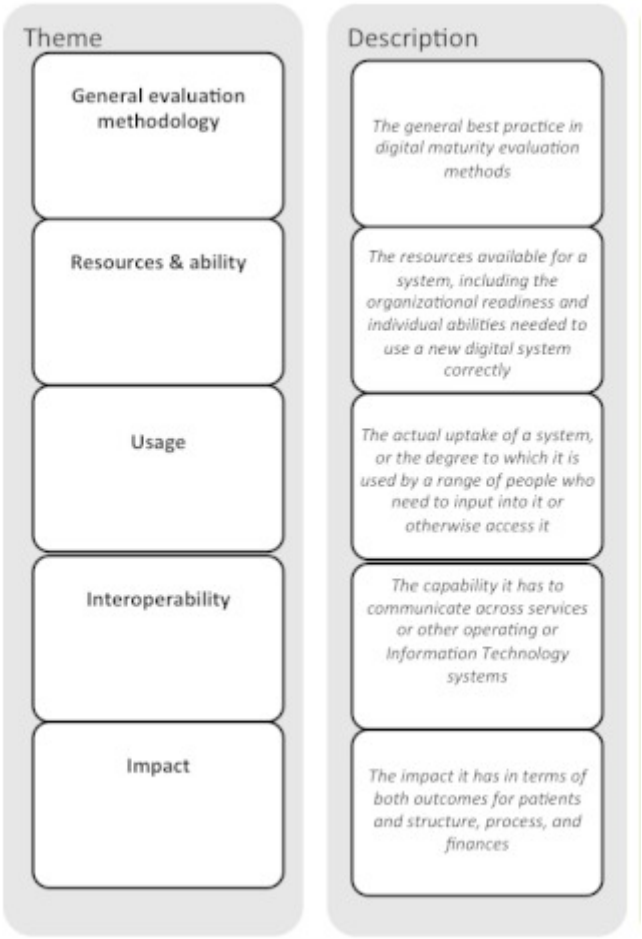
Precision to Decision Big Data Maturity Model



Source:

Skinner, A., Wood, G., Leonard, E., & Stollery, T. (2017). A big data reference architecture for digital agriculture in Australia. Cotton Research and Development Corporation & Data to Decision CRC.

A patient-centred framework for evaluating digital maturity of health services



Source:

Flott, K., Callahan, R., Darzi, A., & Mayer, E. (2016). A patient-centred framework for evaluating digital maturity of health services: A systematic review. *Journal of Medical Internet Research, 18(4),* e75. doi: 10.2196/jmir.5047:10.2196/jmir.5047

South Australian Government's Digital Maturity Assessment Tool

Governance and leadership
The executive support, authorisation, and reporting processes and detailing of roles and responsibilities.

People and culture
The organisation's culture, including customer-focus, innovation, risk appetite and attention to managing change – especially staff roles.

Capacity and capability
The ability to be digitally mature. Resources, staff numbers and skill sets, access to the right technology, training plan, supporting policies and procedures.

Innovation
The willingness and ability to imagine new services and products and new ways of service delivery. Level of proactivity and desire to assess and implement new technologies, business processes and modes of working.

Technology
The suitability of the underlying technology platforms, programs and systems that support the other four pillars.

Digital Maturity Assessment Tool – Governance and leadership

South Australia

Governance and leadership
The executive support, authorisation, and reporting processes and detailing of roles and responsibilities.

1. Read the characteristics of the 5 levels of digital maturity (Minimal to Transformed) and tick any of the characteristics in each level you feel apply to your organisation.
2. Look at the pattern of ticks you've given across Minimal to Transformed and then assess the digital maturity for this pillar and estimate a rating 1 – 5. e.g. if most of your ticks appear in levels *Informal and reactive* and *Transitional*, with hardly any in *Customer-driven*, your rating would be 3 – see the examples at the beginning of this tool. But use your discretion, as some characteristics may have greater weighting than others for your organisation.

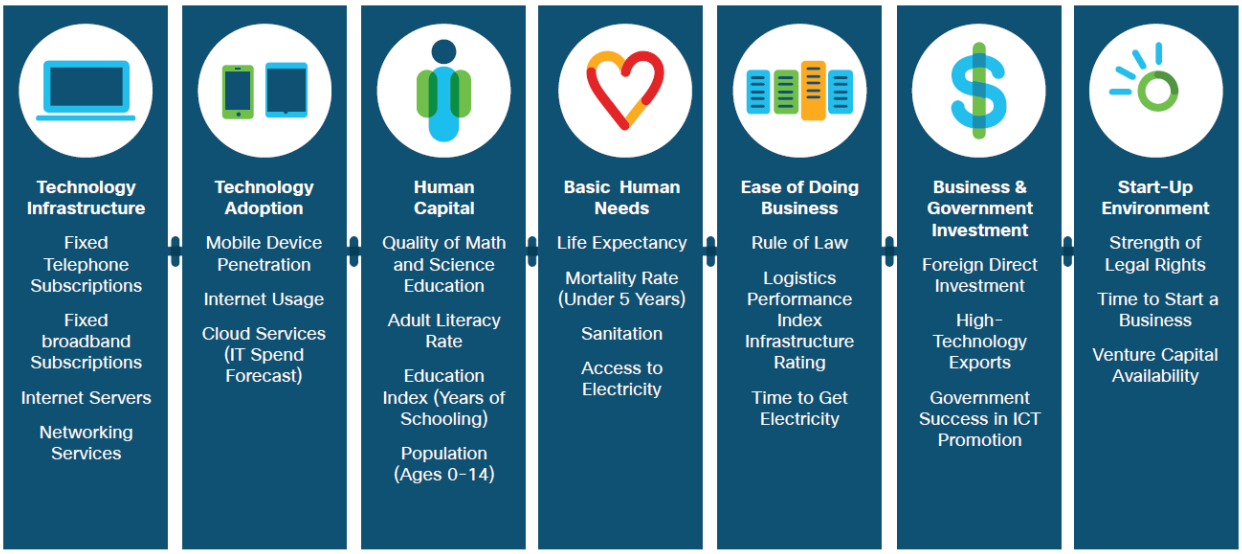
	Level 1 Minimal	Level 2 Informal and reactive	Level 3 Transitional	Level 4 Customer-driven	Level 5 Transformed
Governance and leadership	☐ little buy-in from the executive for digital solutions or strategy ☐ a website exists but there is no departmental digital strategy ☐ digital value proposition not understood or developed ☐ digital opportunities are not understood or defined ☐ ad hoc digital projects initiated by internal groups and individuals ☐ a social media presence or engagement with customers has not been permitted by the executive	☐ value proposition of digital starting to be acknowledged by executive ☐ exploring the impact of innovation and emerging technologies on the business ☐ some one-off collaboration with other departments regarding digital service delivery ☐ social media channels are monitored but social media is seen more as a risk than an opportunity	☐ digital strategy in place ☐ roles and responsibilities for delivering the digital strategy are clear and understood ☐ benefits are well-defined, understood ☐ strategic digital partnerships with other departments ☐ focussed on audiences and their needs and emerging technologies ☐ pro-active engagement with customers across all digital channels ☐ the benefits of social media are understood and drive social media activity	☐ digital strategy integrated into departmental planning process and influences overall organisational strategy and direction ☐ benefits are well-defined, understood and drive all digital activity ☐ KPIs and benefits to the business and customers understood, monitored and reported on ☐ seamless customer experience across all channels – digital and non-digital ☐ strategic collaboration with other departments, utilising multiple channels	☐ digital strategy is embedded in, and indistinguishable from, the organisational vision and strategy ☐ executive understands and fully embraces digital channels and leads by example ☐ new services and products are born digital ☐ non-digital services and products are re-engineered, joined up and re-born as digital ☐ digital services and channels drive the organisational structure and reporting

Your maturity level rating (tick the box): ☐ 1 ☐ 1.5 ☐ 2 ☐ 2.5 ☐ 3 ☐ 3.5 ☐ 4 ☐ 4.5 ☐ 5

Some organisations have quite diverse service offerings and audiences.
For them it may be appropriate to repeat this rating exercise for each distinct area of the organisation.

Source:
https://dpc.sa.gov.au/responsibilities/ict-digital-cyber-security

Cisco's Australian Digital Readiness Index



Source:

Cisco (2018). Australian digital readiness index. https://www.cisco.com/c/dam/m/en_au/digital-readiness/pdfs/digital-readiness-report.pdf

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