

Artificial Intelligence (AI), Rio Tinto and Firm Leading-Edge AI Competitiveness

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ABSTRACT

This study frames AI into five successive generational AI development phases of increasing complex program and platform diversity, whilst drawing on involving increasingly diverse and rich 'global' sources of 'relevant' data. It considers the AI techniques Rio Tinto applies at each generational level. It recognizes the AI complexities of resourcing, technologies, connectivities integrations, intelligent devices, and data-recall capacities on leading-edge firms and their ongoing competitiveness. It proposes a leading-edge firm timeline stagewise strategic AI feedback model.

Keywords: AI generation, big data complexity, AI techniques, strategic AI competitiveness, machine learning, intelligent augmented AI, deep learning AI, super-intelligent AI.

INTRODUCTION

Artificial intelligence (AI) encompasses the ability of a computer program or a digitally connected device to think, learn and respond in a similar way to how humans learn to understand, and influence their environment. This field of programmed interconnectedness technologies also tries to make computing 'smarter'. AI encompasses complex information processing and programming problems that have their origins in some aspects of biological or business data and its' information processing (Marr, 1975). Today's advances in AI have made the sector more complicated and more difficult to deliver high-quality business information in an instant, and this can make the difference between success, or survival, or bankruptcy (Bharadiya, 2023).

Pallathadka et al. (2021) present AI across financial industries as often involving: machine learning, complexities solutions and diversities algorithms, and as helping to achieve: better consumer connectivities, supply chain efficiencies, design improvements, product qualities control methods, and new consumer experiences - and all at low cost! The steady growth in AI applications has now permeated human lives and business opportunities. Today, AI-adoption in business helps anticipate and learn from data. It helps drive competitiveness, re-engineer products/services, remap business strategies, improve human understanding, advances calculations, and solve complex business unknowns (Sestino & De Mauro, 2022).

The AI Business Domain

AI is often based on capabilities being actioned of on functionalities of devices. AI enlists applicable digital AI software systems and offers abilities to analyse and identify basic repetitive patterns, or pattern differences within complex mechanisms including big data optimization, image recognition, machine learning (ML), robotics, and device automation across chosen firm or industrial sectors. Some AI can enable machinery, or devices, to learn and design self-improvements. Zohuri and Moghaddam, (2020) and others support different iteration levels of AI involvement in business processes. AI permeates business at many levels. AI has roughly developed cyclically from simple mechanical rule-based response-driven AI, through to increasingly-complex generational levels of AI as presented below. These five generations align with major shifts in (1) latest digital capabilities and trends, (2) ongoing industrial/developer creative technologies and (3) AI engagement breakthrough cycles. These cycles also marry with futurists considerations (Anon7, 2023, Anon8, 2023), and they are not specifically based on academic papers.

Simple reactive-AI systems receive basic digital information and is programmed to initiate specific responses. This first generation AI system consistently delivers in an unsupervised way, the same basic, specific conditional alterations to the same situation. Further, it does not learn from recurrent or variant digital information situations. Reactive-AI systems cannot initiate future re-directive change actions. However, they can encompass programs including: spam filters, SPSS's statistical analyses, or a Taxi/Uber booking service or a business call-line's filtering system to connect to the chosen business-response sector. This level of software development delivers outcomes like basic AI nature language processing (recognizing/responding and image recognition), but sometimes they may engage basic machine learning and/or neural network algorithms to complete specific tasks.

Second generation AI systems draw upon available memory but in a limited and supervised way. This approach can store knowledge, and use predictive algorithms: to recall, re-collate and train large volumes of data, to compare past and present observed, experiential, or actioning data, and to build further comparative knowledge, whilst also offering complex, assessed,

best-option predictions regarding changeable task components and their redirection. This limited-AI system often involves basic machine learning, and is applicable to chatbox assessments, or to assessing fixed optimal, directed movements of semi-autonomous vehicles in warehouses, or to on-road vehicle activities. However these software-actioned capabilities do not specifically store each specific software action for future differential reuse.

Third generation AI systems involve detailed intelligent augmented machine learning approaches. This computer programming approach delivers coding containing machine language instructions ‘read’ by ‘intelligent’ machines, interpreted as binary program data and augmented with assembly languages or high-level languages via hexadecimal or octal decimal program data. This augmented machine language is designed towards creating very-specific reactive real-time responses - capable of learning, adapting, responding, and sometimes developing specific responses, often along with a degree of ‘reliable’ intuition. However they cannot improve their functionality via gathered experiences, and can only respond to limited combinations of inputs.

For example third generation AI systems (augmented machine learning) are used precise medical measurement devices, or embedded in the operational electronics controlling vehicular engine activities, or in autonomous vehicle detection/control/direction systems or in flight simulators or in movies like ‘top gun maverick’, or even in chess matches, but today can be augmented with voice, virtual realities and powerful computing to merge relevant physical and virtual worlds whilst delivering global real-time digital and logical solutions.

A fourth generation AI system applies more advanced scenarios, data-storage developments and memory management. It operates at a deep-learning AI level and approaches human mind intelligence. This ‘mind’ intelligence AI approach allows emotive, conversational assessment and smarter decision making. It engages fluidity-of thought, memory-recall and emotional intelligence behaviors, and can process human commands and through their deep learning centres, and can adapt findings towards appropriate (and even future-forecasting) communicative interactions. As such, this is a tricky, complex, and comparative, and still-emerging, domain to program. Examples here include intelligent simulators and humanoid robots that mimic human behavior – such as: the ultra-realistic robot ‘Ai-Da Robot’ - who in 2023, both designed and 3D prototyped several commonly-used household items. This area of smart, autonomous robotics continues to expand across: personal assistance, entertainment, healthcare, education, and even into retailing.

A fifth generation AI system is one that can operate super-intelligently as a self-aware-AI instrument of technical, digital, emotional, consciousness, and intelligent competence capable of thinking and operating across multiple mental states. Super-intelligence is driven via specific software interfacing that can enable autonomous machinery to sense, comprehend and enact decisions on their own. Its human-brain inspired artificial neural networks bring the capability of cognitive and natural language towards mimicking, mastering and surpassing human intelligence processes. These artificial neural networks capture structured and unstructured data: as multi-level perceptions, as convolutional neural networking, and as recurrent networking systems - offering combined augmented flexibilities, and providing useful, reliable predictive problem solving deliverables. Examples here include supercomputers –that can resolve almost anything. To date, the fifth generation super-intelligent self-awareness and feelings assessment system has not been delivered, but it is very close and will become reality once the full scope of quantum computing becomes a successful reality.

The above five generations of AI are depicted as Figure 1. Simple reactive AI systems although widespread, generally access lowest levels of acquired data, whereas super-intelligent AI neural networks with vast reach and data complexities operationalize and integrate the other four generations of AI development plus other emerging technologies. Such fifth generation AI systems can potentially scope and solve any emergent inconsistency, or problem, to the level required, and in a very-specific manner.

This study now considers the firm Rio Tinto as a lead example of how key generational-level AI-related techniques can deliver results. This study recognizes AI operates across an expanding continuum where complexities of resourcing, engaged technologies, network-linked connectivities integrations, intelligent physical and virtual devices, and data-recall capabilities It recognizes each engaged technique presents business enhancements that when incorporated can influence overall firm operations whilst also delivering ongoing global, competitiveness repositioning.

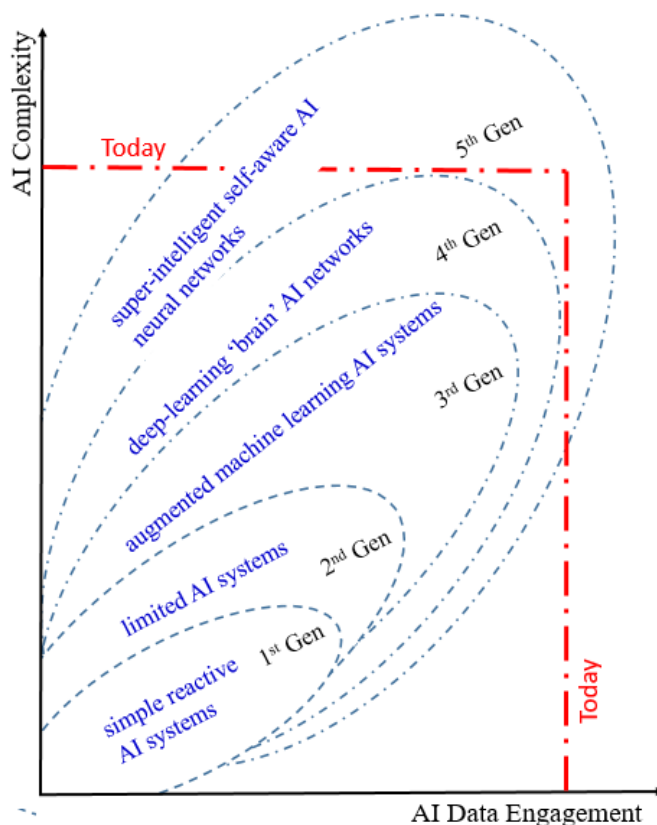
LITERATURE REVIEW

Rio Tinto’s Leading-Edge AI Business Model

Rio Tinto has existed for 150+years, and today is the second largest global mining company. It operates in 35 countries and has a workforce of around 52,000 across six continents. Rio Tinto’s portfolio includes iron ore, copper, aluminium, lithium plus other materials required for everyday life, and for a world transition towards net zero carbon emissions. Its market capitalization is USD 130.24B (Anon1, 2022).

Across the last four 2019 -2022 financial years, Rio Tinto’s gross sale revenue ranged from USD 43.165B to USD 63495B, and its current 2022/23 financial year gross sales revenue is USD 55,554B. By mid 2028 shares in Rio Tinto are projected to grow by around +6.44% (Anon1, 2022).

Rio Tinto is focused towards best operator, with greater consistency in operational performance, whilst delivering impeccable environmental, social, and governance credentials, excelling in development, and strengthening its social licence. In-line with societal decarbonizing, Rio Tinto is also shifting to underground autonomous vehicles and renewable power. This is driving demand for more copper aluminium, lithium and high-quality iron ore from globally competitive mines. Thus Rio Tinto focuses towards finding better ways to work and towards a determination to innovate. Hence it strives to create partnerships in solving problems, to create win-win, and to meeting opportunities, whilst also being a business with a commodity-mix aligned with evolving customer demand in a decarbonizing world. Thus it aims to find better ways to engage its DNA (Anon1, 2022).



Source: This study.

Figure 1: Specificity/complexity of data deployed under successive generations of AI

Rio Tinto engages new technologies, data science, machine learning and artificial intelligence throughout their current strategic business model. Their need for innovation is continually growing as are their ways of producing materials like aluminium and scandium. They already sustainably block-chain-label their aluminium product, and have sold iron ore and aluminium via block chain. The beneficial outcome of copper, aluminium, iron ore, lithium and other minerals towards net zero or renewable energy production are improved and continually monitored. Mine yields and efficiencies, along with the lowering of waste streams, are continually improved (Anon2, 2022).

Globally, Rio Tinto has access to over four million hectares of land Its 2023 R&D technology roadmap aims to explore, design, build, operate and close chosen operations by improving productivity, maximizing value from each orebody, equipment utilization, automation, energy efficiency, energy storage, green processing, reducing capital intensity, reducing water consumption reducing frontline hazards, and people wellbeing management (Anon1, 2022).

Rio Tinto Digitally Connected Techniques

Since April 2019 ‘Gudai-Darri’ is Rio Tinto’s most technologically advanced iron ore mine. it engages over one hundred digital technologies, some of which are presented in Table 1, with each displayed diagrammatically across the rows of Figure 2 below. To date Rio Tinto has delivered generation 1 to generation 4 AI solutions across its mines, and it continues to develop further generation 4 and 5 AI technologies (marked as capital red ‘X’). But, it has not yet delivered generation 5 AI solutions.

Today Rio Tinto’s AI is predominantly working towards or at generation 4 AI levels. However, its innovation continues to advance with these four generations. For example, its new Bioiron (trademark IP) approach enlists sustainable biomass, microwave energy and AI to efficiently replace coal across the iron to steel reduction process. This also enhances its decarbonization.

The fifth generation AI system with super-intelligence, self-awareness, emotional consciousness, and sensory capabilities across multiple mental states is now being targeted by Rio Tinto as a precursor model prior to the completion of quantum

computers. Quantum computing offers the potential introduction of robotically-interfacing self-modifying autonomous machinery – possibly collectively deploying AI-supported neural networks, senses, comparisons, comprehensions, and machine-specific smart decisions. This structured and unstructured big data intelligence level likely surpasses human intelligences, offering combined augmented autonomous functionality flexibilities, whilst also providing optimized predictive problem solving activity analytics. Thus Rio Tinto continues to draw on creative technologies and build new innovative AI techniques and applications that likely facilitate an enhanced AI-supported competitiveness position.

Table 1: AI Deployment Techniques and Applications at Rio Tinto
Rio Tinto Iron Ore AI Engaged in Australian Mining Operations

AI Deployed	Gen 1	Gen 2	Gen 3	Gen 4	Gen 5
1 Near-real-time robotic ore sampling/grading/mine-feedback laboratory plus the data analytics	x	x			
2 23*CAT 793F battery-driven autonomous haul trucks	x	x			
3 4*CATMD autonomous drills	x	x	x		
4 Autonomous dust suppression water carts	x	x			
5 Autonomous dozers, graders, loaders, and shovels complete mine operational fleet - with iron ore grades controlled by blast hole data	x	x			
6 World's first fully autonomous and remotely monitored long distance, heavy-haul rail network, and in the future maybe ships	x	x	x		
7 Digital replica processing plant to pretest situations before processing	x	x	x	x	X
8 Mine digital twinning (visually navigates physical asset, plans work against 3D (to scale) gaming engine model & accesses/views associated AI tech data & documents and VR interactively PLUS virtually trains operators	x	x	x	x	X
9 34MW (83000 solar panels) on-site solar/wind powering 33% of the mines requirements plus a 1GW off-site solar/wind additional renewables power support system	x				
10 Field mobility devices for all personnel	x	x	x		
11 Low maintenance down-time removable rotatable 74 bucketwheel reclaimer	x				
12 Heavy mobile equipment (HME) warehouse robotics and laser-guided automatic vehicles to IoT automate pallet frame handling	x	x	x		
13 Real-time tablet solutions (paperless field mobility)	x	x	x		
14 Master remote control of all field operations	x	x	x	x	
15 Digital training and field-action simulators	x	x	x	x	
16 Mining artificial intelligence	x	x	x	x	X
17 Sensor based ore sorting	x				
18 Mine-of-Future layered technologies	x	x	x	x	X
19 3D mine analysis gaming engine sees inside operations, dives down for detailed information	x	x	x		
20 Robotic drilling and ore sampling	x	x	x		
21 Big data 3D analysis	x	x	x		
22 Immersive technologies	x	x	x	x	
23 Near-earth drones data robotics autonomy	x	x	x		
24 Mine-to-port VR oversight	x	x	x		
25 VR drone meshing	x	x	x	x	
26 Remote VR warehouse monitoring	x	x	x		
27 Value chain visualization	x	x	x	X	X
28 Holistic digital mine site exploration	x	x	x	x	

RED 'X' = DEVELOPING

1 Robotic Lab Sampling



5 Autonomous Grader

2 Haul Truck



6 AI Train

3Autonomous Drill



7 Digital 3D Mine/Plant

4 Robot Water Cart



8 Digital Twinning

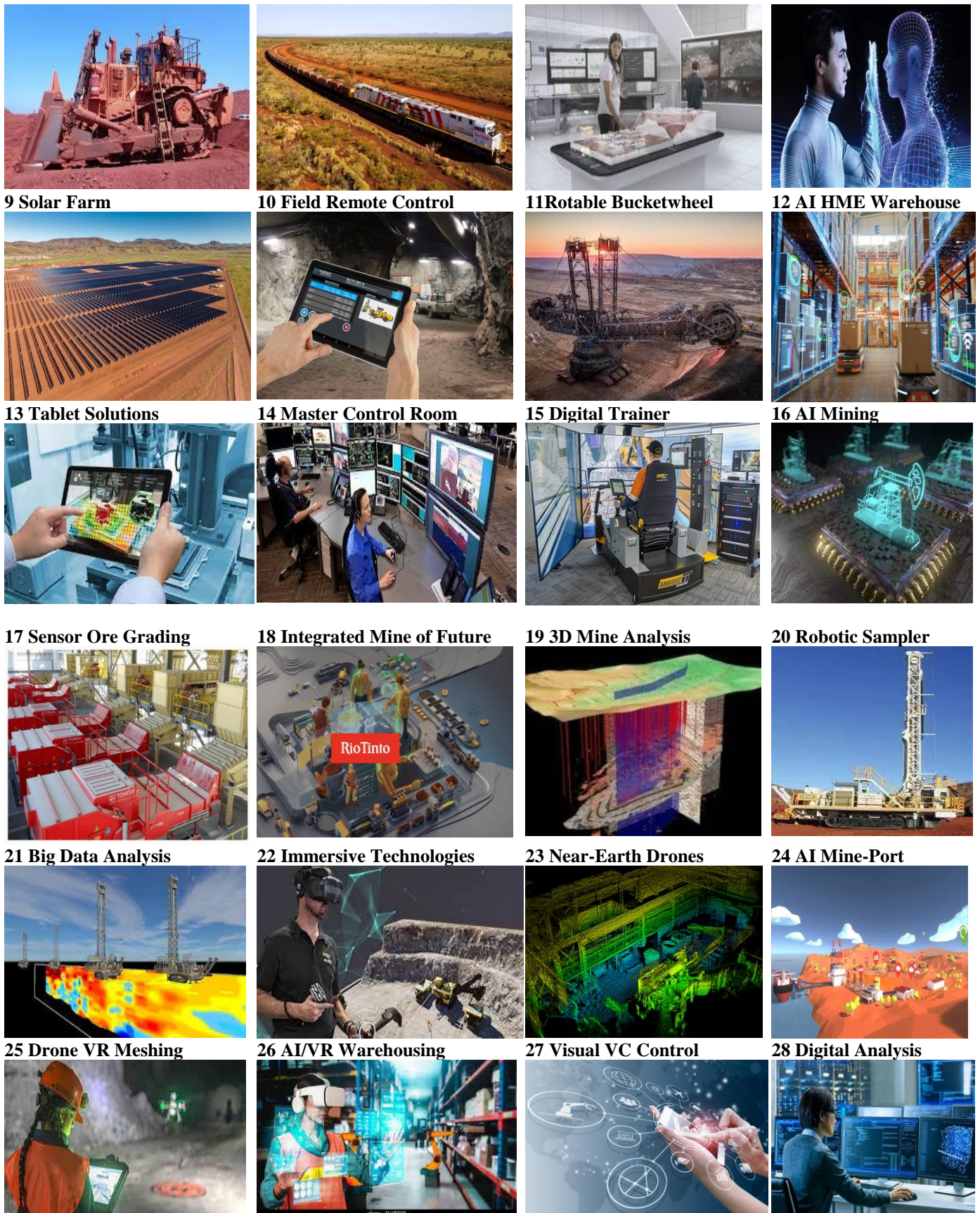


Figure 2: Rio Tinto Digitally-Related Techniques (sources Google Images and RioTinto.com)

ANALYSIS

Mine Meshing

Rio Tinto continues to enhance its new-age logistics approach as a mine mesh - integrating all its digital global intelligence systems across multiple platforms and servers. These integrate into a seamless pit-to-port, layered, 3D/4D continually-updating

process line, where all experiences and decision making is possible by intelligent machines or by human overrides (Anon2, 2022).

Today the world's most intelligent mine (Gudai-Darri) continues to disrupt traditional mining (Chan, 2022). It continues working towards the cohesive and collective networking of all assets into one digital connectivities decision making system - where any decision can be made 'in a microsecond.' Mine meshing brings digital full-mine visibility. For example Microsoft Azure's digital twinning gathers, integrates and extracts data and special intelligence graphs into models and interactions from across the mine's real world IoE sensors. It adds historical data and allows real-world interface modelling of the entire value relationships and interactions between the mine operator, spaces, and devices. This allows a drill down to individual assets and AI predicted setting suggestions, and to then make informed decisions with ability to simulate/predict downstream effects of such planned actions. Thus changes can be assessed and implemented virtually with an overall aim to deliver a system which understands in microsecond, manages an unplanned event, assesses past experiences, uses market intelligences and ensures value-over-volume (Anon6, 2023).

Mine meshing technology provides interconnected, seamless, overall digital mine experience, visibility, and toolkits to optimize productivity. Currently, there are more than one hundred approaches that mining incorporates including:

- Augmented realities (AR) where the mine mesh sees (1) digital processing plant real-time accessibilities (workforce, or fully integrated automation/autonomous/simulation systems), (2) technologies interconnecting logistics and the entire mining value chain, and (3) real-time sampled, lab-analyzed ore-body control-limit data.
- An autonomous drilling system (ADS) that safely tracks and pursues best grade seams of the ore body
- Remote in-city operators/controllers engaging analytics, machine learning and robotics to drive improvements in mining and/or business outcomes
- Virtual reality (VR) modules enable the solution to complex activities
- Mixed reality (MR) and extended reality (XR) simulations to test and/or guide new approaches
- 360 degrees 'complete' surroundings capture of any task allowing the on-demand workforce to fix problems and reset tasks
- Smart (autonomous) robotics capturing data everywhere as an internet of everything (IoE)
- Drone GPS mapping, recording across mine and logistical activities engages Rio Tinto's visualisation 3D gaming engine. It allows viewing over a site, collecting diagnostics, and assessing against accumulated information.
- Remotely operated vehicles (ROVs) real-time 3D mapping and checking slopes, crests and walls for safety risks, etc.
- Data-driven mine assets capturing and adding to digital IoE integration
- Marketplace-led demand-driven logistical supply chain actions specifically-generating additional value capabilities and delivering secure, real-time targeted outcomes
- Blockchain security across chosen contracted deliverable product mixes
- Agile, specific, block-chain labelled, blending/combining of mine ore grades to best-fit-end-user processing requirements and enable agile qualities/blending responses linked to marketplace demands
- Machine learning and predictive analytics help anticipate marketplace conditions and guide better mine output decision making
- Real-time mine mesh visualization across Australian mining operations through to the Singapore sales/marketing hub allows optimized shipping schedules of (what cargo, what size, what grade, what timeframe, what destination, what ship)
- Integrated GPS tracking of ships (largest biggest-draft-ships aimed to deepest berth pockets)
- Rio's AI historical data tells best mine ore to use for particular end-user order
- Advanced resource management system planning systems now reduce 3-to-4 weeks historical scheduling to 2 days
- AI/BI and big data technologies data sharing includes digital partners like Microsoft, Apple, Caterpillar, etc.
- AI software encompasses: locations, speeds, directions materials, efficiencies, safely, productivity, predictive maths, clever computer coding, powerful multi-level software, operations centres adding identified opportunities for improvements/efficiencies, geology, geotechnical, drill/blast, production/planning, visualized surfaces/sub-surface features, integrates analytics/sensory tools for better decision-making
- Dynamic learning systems operating within mesh visualizations
- Sustainable mine decarbonizing by lessening diesel fuels and engaging substitute enviro fuels
- Decarbonizing energy demands using solar and wind renewables.

DISCUSSION

Rio Tinto remains on a progressive pathway to advancement, low cost delivery, and consumer connectivity. It remains not yet satisfied with its total suite of deliverables, and it still imagines things like at Gudai-Darri using predictive analytics to self-check machinery component conditions and to use AI and AR to check as required before non-scheduled maintenance can occur. This in-turn minimizes downtime. Currently Rio Tinto is focused on the following five domains

- Sustainability and a move towards zero emissions, along with digital connectivities to drive real-time efficiencies
- Predictive analytics to deliver real-time scheduling/tracking/ordering, augmented realities, and smart resource allocation solutions

- Mine ventilation-on-demand to reduce energy consumption underground below its current 50% of underground mining cost
- All electric and electronic digital mining delivered through autonomous and digital solutions each reducing costs and contributing towards further decarbonization
- Global logistics ensuring complete mine to client individual order completion is just-in-time (JIT) delivered as the desired ‘matched product to end-user requirement.

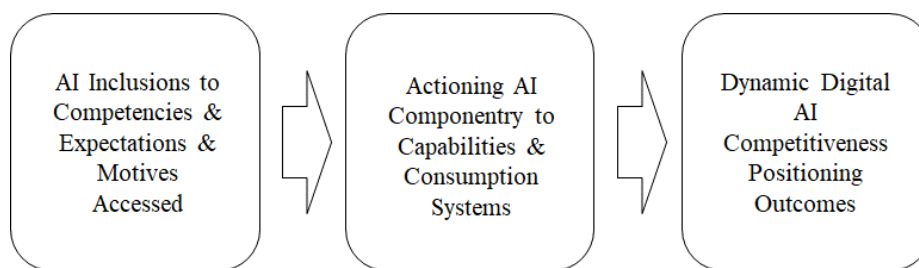
Thus at Rio Tinto, sustainability, real-time predictive analytics, mine efficiencies, mine ventilation-on-demand, all autonomous/electric machinery, and JIT globally-connected remote-management control logistics networks, pervade all operational capabilities thinking. To optimally achieve these actions, Rio Tinto engage latest applicable creative technologies. They build internal capacities to help them successfully build and optimally mine. They continually innovate with specifically-skilled partners to improve everything they do. They use unique selections of resources smartly, efficiently and effectively. They up-skill their workforce to competently multi-task and interact with the virtual world. They engage their current and emergent intellectual properties and preserve their unique competencies as a foil against copy-cat rivals.

These all constitute a suite of essential competencies precursors required by Rio Tinto to support and help optimize their mining capabilities. These optimal operational capabilities are values driven, risks minimized, system connectivities networked, marketplace serving, and end-user consumer connected. As a suite of capabilities they network-combine and digitally integrate as a coalesced enhancement solution focused towards delivering a decarbonized, sustainable, intelligent, competitiveness that positions them strongly against their rivals.

Rio Tinto, like many firms, builds-up and enhances its competitiveness position over time, but Rio Tinto works diligently to remain a global leader in lowest-cost, ultra-efficient, high-tech mining. As per Figure 1, and across all five generations of AI, specificity and complexity of data deployed under successive generations of AI is helping Rio Tinto develop its digital competencies, better-action its capabilities, and focus towards being an even more competitive miner in the future.

Thus, where other leading-edge firms also choose to grow their leading-edge competitiveness, AI is likely an essential, and increasingly complex, business enabling component, requiring relevant ingredients from across all five of Figure 1’s AI generations. This alone requires advanced coding and extensive data capture and cloud storage. It is also likely that across a compact timeframe, leading-edge firms must strategically consider and deploy multiple AI generations together and also incorporate multiple platforms of IoE smart devices. This likely means they may need to understand more precisely how their business operates and delivers it ongoing AI competitiveness against rivals.

Ongoing firm competitiveness is a possible business outcome targeted position, derived through the skilful use of firm available, astutely-sourced and well-guarded, technological innovations and capacities. These competencies support the firm’s value adding actions, risks mitigations, and consumer and marketplace connectivities. These capabilities suites, along with their supporting competencies, present a useful network that can focus towards delivering an enhanced competitiveness position (Hamilton et al. (2020). Figure 3 offers a general competitiveness model structure specifically focused towards AI.



Source: This study & further model-adapted from Hamilton et al. (2023).

Figure 3: Strategic AI feedback model

Figure 3 also likely applies to smaller firms pursuing leading-edge approaches to AI. This study’s lead author is currently investigating Figure 3’s strategic AI feedback model separately and at three levels (global, industry, and firm). These differing firm-sized approaches are each structural equation modelling analysed. Results to date show a complex connectivities network solution does exist across these three stagewise AI development blocks.

CONCLUSION

AI is not simple. AI is integrated into the firm to help achieve chosen strategies or targets. AI can be delivered across one or more of five generations of inclusion – from the first generation of least complexity through to the fifth generation of most complexity. AI across all generations continues to improve as machinery, devices, creative technologies, computing power and

innovation continue to improve. AI is a capabilities and functionalities strategic-build inclusion. It is likely best incorporated to help drive and enhance an overall competitiveness position.

Since 2006, Rio Tinto has remained on the mining technologies advancement pathway. Its achievements over time are substantive, productive, and leading-edge. It is now recognized as the most technologically advanced iron ore miner in the world (Chan, 2022), but it is not yet the most profitable global miner. Hence, it remains on positive competitiveness pathway against rivals.

AI competitiveness likely remains a digitally-related stagewise firm development. The leading-edge firm builds an AI mesh network that captures firm-wide technologies across multiple servers and seamlessly integrates them into a network of expectations, experiences and competitiveness outcomes.

First the leading-edge firm acquires a suite of necessary competitive business competencies. It supports each of the firm's leading-edge digital competencies with separate, specific, relevant AI inclusions which include integral, digital, enabler/learner/extender componentry.

Second, the leading-edge firm collectively enlists these AI-supported competencies as a combined suite of competitive digital enablers, specifically-focused towards innovatively optimizing/actioning each available key AI capabilities system into coalesced and measured AI-networked outcomes.

Third in an ongoing manner, the leading-edge firm then contributes its competencies and capabilities network towards enhancing its overall dynamic AI competitiveness positioning against rivals.

As a change driver, it is very likely AI can be successfully measured. Key areas of AI include machine learning, machine support vectoring, digital learning, deep learning, natural language processing, artificial neural networks, autonomous automation, machine visioning, and sensing. AI and its related data, can be captured, assessed, and adjusted for each AI application or inclusion. This useable information can be captured across Figure 3's stagewise strategic feedback model. Further, this approach also applies at generation 1 through to generation 5 applications, and either as single generation or multi-generation application system inclusion.

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