Using AI to **fast-track manufacturing operations**

From optimising quality control and predictive maintenance to transforming material handling and tooling, AI can aid in streamlining critical processes. **Pallab De** and **Prahalad Chandrasekharan** delve into the transformative potential of AI while underlining the risks that could surface with such a technological leap.

- **45%** of total economic gains by 2030 will come from product enhancements stimulating consumer demand, as AI will drive greater product variety with increased personalisation, attractiveness and affordability over time.[8]
- AI-enabled predictive maintenance could reduce maintenance costs by up to **30%** and unplanned downtime by **45%**.[9]
- **94%** of organisations believe that AI will help create more opportunities than be a threat to their industry.[10]

The uses of AI in operations consulting are manifold. From improving the quality of products and processes to the use of robots for autonomous decision-making to optimising and reducing overall supply chain costs, AI is all pervasive – a must-have rather than a nice-to-have technology.

8 Sizing the prize: PwC's Global Artificial Intelligence Study: Exploiting the AI revolution

9 https://thedatascientist.com/data-automation-and-british-manufacturing/

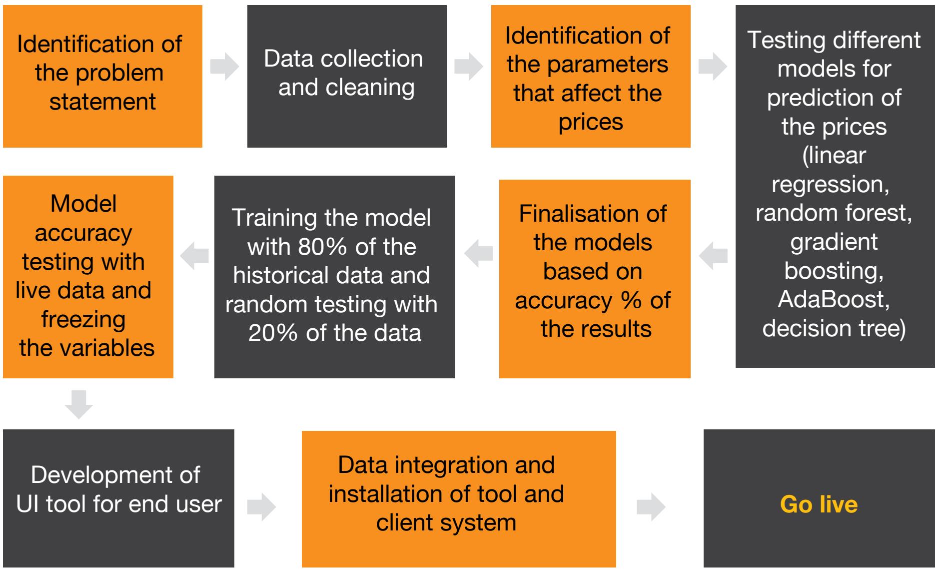
10 AI: An opportunity amidst a crisis, a PwC India report

While companies are already benefitting from using AI in numerous application areas, it is surprising to note that 38% of Indian companies that had participated in a PwC India survey recently revealed that they do not have any plans to adopt digital technology for their businesses.[11] One of the reasons could be the way technology programmes are implemented and managed. Having said that, it is important for manufacturing companies to embrace change and focus on digital transformation to stay relevant in the dynamic global ecosystem and reap the benefits of AI-based solutions.

Following are some instances where PwC has partnered with clients to deliver AI-based solutions:

- In an engagement with a capital equipment supplier, PwC provided an AI-based model for predicting trailer rates based on the random forest gradient boosting method. The successful adoption of this model led to a 10% reduction in logistics cost base.[12]
- For a manufacturer of ferro alloys in India, PwC facilitated the creation of an AI-based model for accretion reduction in direct reduced iron (DRI) kilns. Over 30 parameters were identified to build a successful model and develop a two-hour forecasting model which is installed in the distributed control system (DCS) terminal. Every two hours, the model predicts the output and indicates what parameters to change (secondary air flow in various chambers, coal throw, primary air flow) to the kiln operator. The kiln operator is expected to follow the model's outputs and change the parameters accordingly. This is a good example of the application of AI as a decision support system.
- PwC also facilitated the implementation of a vehicle routing problem (VRP) solver with a cloud fleet routing request, to optimise distribution costs for a large conglomerate in Bangladesh. The tool implements a randomised version of the Clarke-Wright savings algorithm for vehicle routing problems. It takes input from a text file listing each customer's location (latitude and longitude) and demand. Distances may be entered explicitly or computed automatically using Euclidean or great-circle metrics/maps. This tool has helped to optimise the distance travelled by the fleet by 15% for the business units in scope and improved distribution planning.[13]

Figure 1: A recommended structured approach for AI implementation



11 PwC India report: Reimagining digital factories of tomorrow

12 Percentage based on PwC analysis

13 Percentage based on PwC analysis

However, implementation of such AI models is not without certain risks and challenges. One such challenge is driving change management while implementing such models, and ensuring that the change sticks. The implications of AI in manufacturing operations are also raising concerns around data intensiveness, use cases and whether the benefits outweigh the associated costs.

Though AI has certain limitations that will require considerable effort to overcome, it is also a moving target that promises advances to create new opportunities. A deep dive into the benefits and associated costs of AI in manufacturing operations may help businesses weigh the pros and cons. However, given that AI may be used in a variety of ways including but not limited to removing bias, improving productivity and decision-making using predictive levers, it may help to first gain some insights from a few use cases.

AI's pivotal role in building manufacturing operations of the future

Following are the areas where AI is supporting manufacturing operations functions to stay one step ahead in times of change:

01 Quality control

02 Maintenance

03 Design

04 Sales

05 Material handling

06 Tooling

1. Quality control

In situations where visual inspections are required, AI, with a trained dataset, is effective in eliminating human bias and providing accurate outcomes.

Let us consider some common use cases of visual inspection. For instance, in a glass bottle manufacturing plant, there is usually a conveyor through which, post-production, bottles pass an inspection station where quality control operators accept/reject bottles based on visual defects such as scratches, blemishes, shade gradation variation, bubbles and minor spots. Some of these defects are only visible to a highly trained eye, and given the high degree of focus required, statistically there are possibilities of type 1 (reject a good bottle) or a type 2 (accept a defective bottle) error. Sometimes such mistakes can cause significant customer dissatisfaction and to avoid this, there is one more inspection on a sampling basis before the final dispatch. This is not only effort intensive, but also a wasteful process.

AI's role: An in-line camera sensor which can capture a 360-degree image of the bottles in the line and has the ability to map the data back to the various categories of defects and provide an accept/reject outcome could solve this problem and improve the quality and efficiency of the inspection process. As the number of inspections increase, the data gets populated further and the outcomes become more accurate. However, the prerequisite for AI to be implemented in the process is to have large volumes of data/images for each of the defect categories so that the AI algorithm can be trained to eliminate the bias in its assessment.

As the next step, the ability to monitor and plot control charts, use the seven principles of control chart interpretation (outliers, 2 consecutive points above 2 sigma limits) and map them back to the process parameters that resulted in these defects can further help in enhancing the process control through a feedback loop.

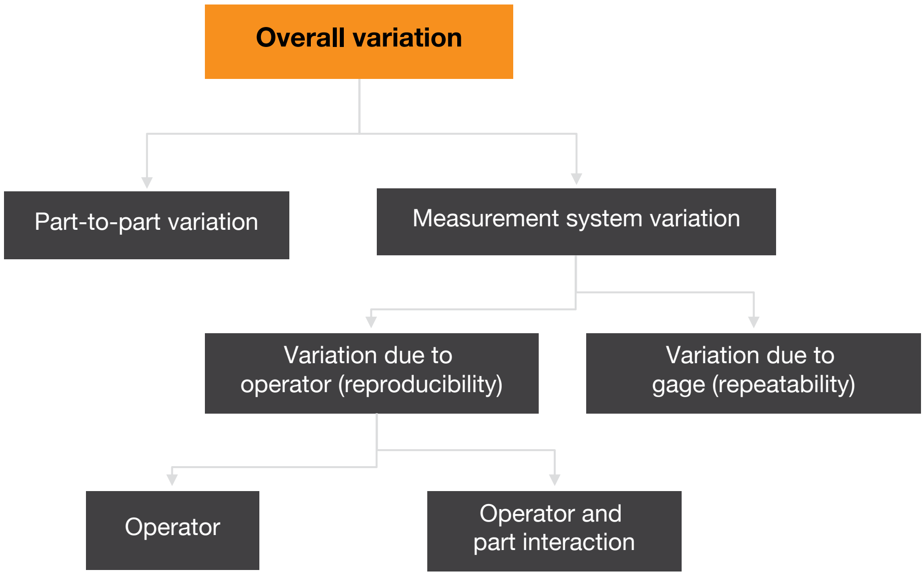
Over a period of time, the system would then be able to analyse process parameter deviations from the norm intelligently and, instead of noticing control chart parameters on finished products, the system can start monitoring the control chart for process parameter deviations and correct them at source or provide alerts to supervisors for correction. This would help businesses move from a reactive to a pro-active stage.

This proactive stance in a manufacturing environment can enable businesses to address defects at the source even before they appear in the product. The maker-checker process can also be minimised resulting in a reduction in the number of inspections.

Another use case would be in the automotive industry which requires an accurate visual defect identification of painted surfaces. Currently, due to manual inspection, this process has certain levels of subjectivity which can be addressed using the power of AI. AI can learn to classify the defective painted surfaces from non-defective ones through vast data, eliminate subjectivity and provide more accurate outcomes.

The use cases of AI pertaining to quality control are evolving rapidly and companies need to adopt AI-based solutions on a rigorous evaluation of return on investments. Accordingly, the skill set required for a quality control personnel has to evolve in tandem with the newer ways of working. Resources will no longer have to specialise in measurements but will need to be equipped to interpret the signals which the AI provides. They also need to be made aware of the technology behind the AI, at least at a basic level, with a focus on the use cases where AI can be beneficial for their day-to-day tasks. AI can effectively improve the measurement system.

Figure 2: A well-trained AI tool can help in reducing variations emanating from the 'reproducibility' parameter



$$\sigma^2_{\text{Total}} = \sigma^2_{\text{Process}} + \sigma^2_{\text{Measurement system}}$$

2. Maintenance

With the ability to track the mean time between failures (MTBF) trends and detect early warning signals, AI may effectively prevent unplanned outages. This is particularly useful in critical equipment where uptime requirements are close to 100%. Maintenance functions have been trying to move from preventive to predictive maintenance, and with AI this goal is well within reach.

At present, most companies follow time-based maintenance for their equipment and have schedules such as preventive maintenance once in six months. However, this does not guarantee that an equipment failure will not occur in the interim.

AI's role: With a wide variety of failure modes and causes pertaining to an equipment being fed in as training data, AI-based tools can start looking for similar likely events when the equipment is under operation. For example, if a critical equipment has had repeated motor failure due to various causes such as heating of bearing or overload of equipment, the company can invest in thermal scanning of bearing while the equipment is under operation and load parameter monitoring. This way, any deviation from expected temperature and load can trigger an alarm/alert for the maintenance technician to take quick action.

An added benefit of adopting AI is the ability to manage requirements for spares since AI will be able to predict the failure frequency. Experience suggests that spares are generally managed through a vital, essential and desirable classification with certain levels of inventory holding. In most manufacturing environments, ageing of spares is an important concern. With AI, one may be able to accurately predict when a spare would be required and then plan to procure it when needed. This not only reduces non-moving inventory, but also helps recalibrate the vital, essential and desirable spares.

There is a wide variety of use cases of AI in predictive maintenance, and a good application of the technology could be in planning the shutdown maintenance of a kiln in the ceramic industry. Most shutdowns today are planned based on time/cycles of operation, however, with AI, this can be shifted to maintenance based on proactive triggers.

3. Design

For businesses which operate on responding to tenders, it is important to quickly bring out a solution at the bidding stage so that the bids can be submitted on time. The computational ability of AI can design solutions quickly and objectively with the help of training data. In an engineer-to-order environment, products may have to undergo incremental changes to meet certain client-specific requirements. The incremental changes which are required in the product could be a new feature or a new performance parameter requirement. For example, one of the requirements could be a lighter product for the same strength specifications. In such scenarios, if people need to look for solutions or prototypes with various permutations and combinations, the time to find a solution will be very high.

AI's role: If all product features, and corresponding performance requirements are made available as data points to an AI algorithm, the AI, over a period of time, will be able to suggest the best material and process combination that can meet the performance parameter for any incremental changes that are required for the product.

This aspect of AI can be useful in an engineer-to-order environment, such as the defence sector, where companies can leverage AI to get the best strength for a protective equipment for a given cost and weight consideration.

4. Sales

AI, coupled with a vast amount of point of sales (PoS) data and an ability to recognise patterns, can accelerate sales for a variant/depot combination. Recommendations made on supply chain networks and footprints based on emerging trends in consumption can contribute to boosting the sales of a product.

Take the example of rooftop solar systems. The panels and accessories are generally supplied through a channel partner which is replenished by a depot. Since this is a sunrise industry, the demand can be quite unpredictable and the customers for these categories also have options to switch if a local dealer doesn't have stocks of the product that they are looking for. For end customers, this is a cash and carry option, therefore, it is important to have the right inventory close to the source of consumption.

AI's role: Based on historic consumption and demand patterns, analysis of lost sales due to stock-outs, and cross shipments across depots, AI can help identify the right inventories to be kept at each consumption point. Over a period of time, based on heat map of consumption and replenishment points, AI can also provide intelligence on how the network should be organised to feed the demand using certain decision parameters such as consumption frequency, replenishment time and customer's willingness to wait. AI can help rationalise inventory holding across the supply chain, in addition to enhancing sales.

5. **Material handling**

Material handling, which involves movement, control, storage and protection of goods through the different stages of manufacturing, distribution and consumption plays a crucial role in supply chain management and logistics with efficiency and productivity being the focal areas of attention.

AI's role: The adoption of AI tools, enhanced by deep learning, can optimise transportation index within a plant for mobile material handling equipment and can also suggest layout modifications to reduce transportation index. Leveraging AI in planning milk runs within a plant for movement of materials according to the production run, along with the optimised transportation index may boost the production capability of the plant.

6. **Tooling**

Tooling is essential for manufacturing, production, assembly and other operations to ensure that tasks are performed with precision.

AI's role: Through monitoring and analysis of tool usage and tool wear, AI technology can be leveraged to predict the remaining useful life of the tool and spares management for tools. An example of this is in fabrication shops where the punch and die process can be closely monitored through image scanning and a plan for refurbishment of the tools can be made well in advance.

While the example demonstrates AI's role in manufacturing operations, the technology can also be used in other business processes such as workforce planning, procurement, logistics and store management. The application of AI will depend on the type and nature of the industry, maturity of operations, product life cycle and other factors.

Limitations of AI

While AI's application in solving business problems extends across nearly every sector of the economy, the limitations in implementing AI to overcome real-world challenges could at times discourage leaders from reinvesting in it. The questions which arise while adopting AI in business operations are:

- How does one determine where to draw the line in the use of AI in business functions?
- How does one decide when to stop so that the cost does not outweigh the benefits?

One way to address these concerns is to evaluate AI applications through an impact versus cost matrix and choose areas where the returns on investments are higher.

When it comes to manufacturing operations, AI has been beneficial in key areas of operational metrics such as

- cost of poor quality (COPQ) reduction
- overall equipment effectiveness (OEE) improvement
- order to delivery lead time reduction.

Organisations need to have some foundational elements in place for successfully leveraging AI. First, it is essential to understand the concept of 'measuring what matters'. Granular data elements, which are generally not collected in day-to-day operations, need to be collected for effective base lining and reasons behind current baseline performance need to be understood.

Figure 3: Measuring what matters starts with understanding customer requirements and converting them to critical to quality (CTQ) parameters

In a particular implementation, a company had certain standard units per hour in their manufacturing line. When the actual units per hour were measured, they were at 80% of standard with a difference of 20%. Though line stops due to unavailability of manpower or changeover times could explain the difference of 10%, the company did not have the parameters to explain the remaining 10% of the losses.

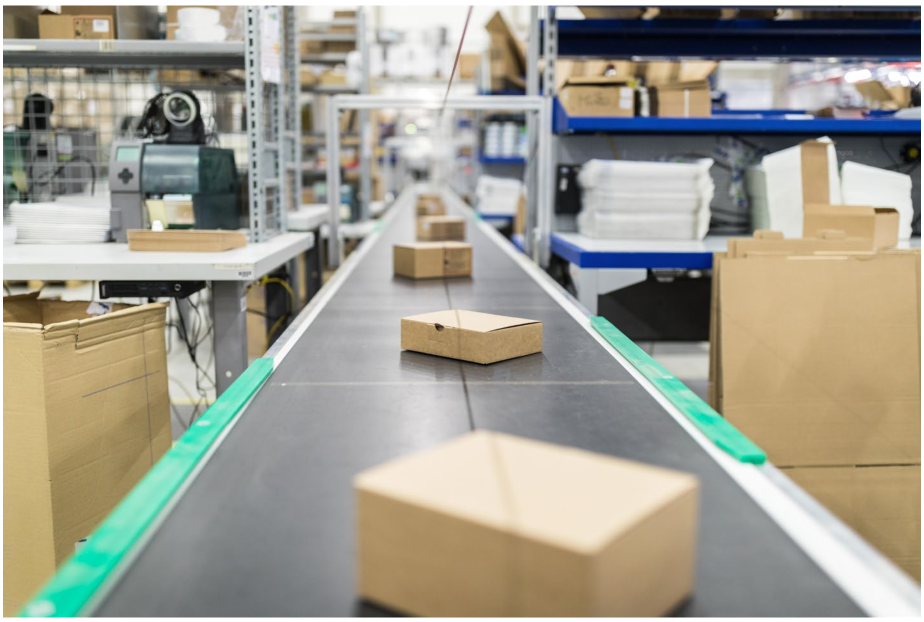
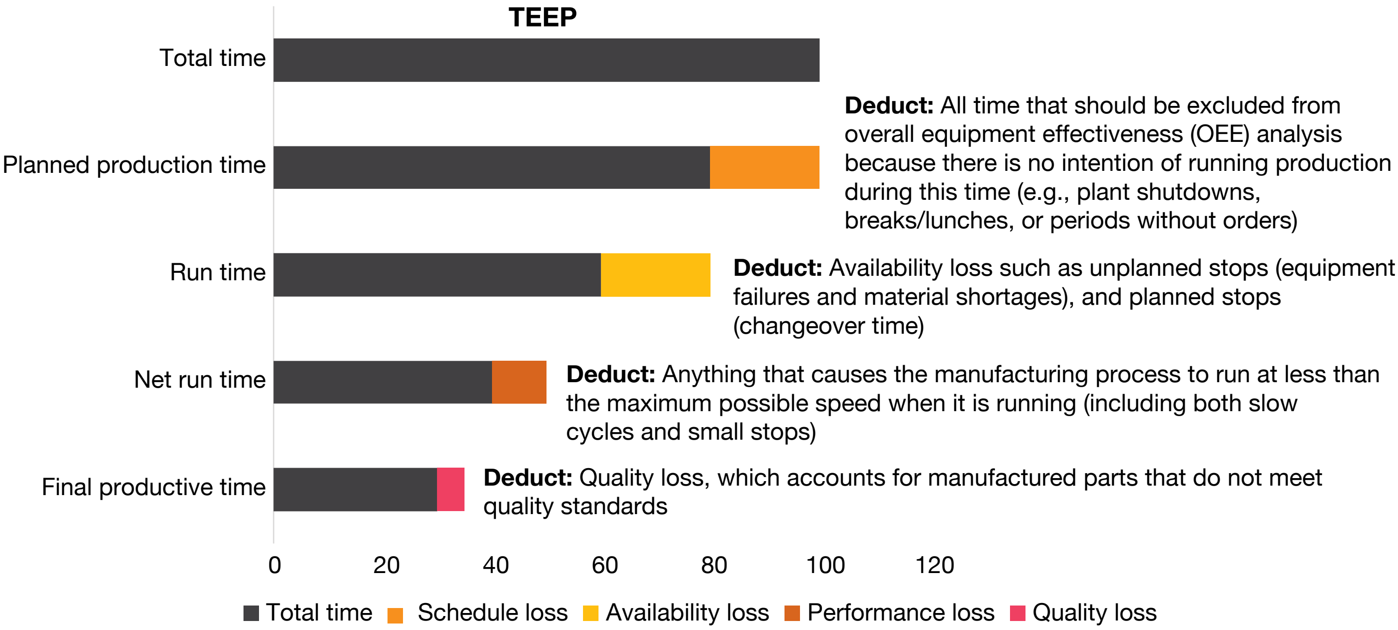


Figure 4: Plant assessment is recommended to be done through total effective equipment performance (TEEP) evaluation



Therefore, a prerequisite for getting the best outcomes and deriving real time benefits is to ensure the right quality, specific duration and source of data, along with investing proactively in data collection and automation of the collection process. Optimal quality data can be generated by moving to a single source of data when the data is obtained directly from the system, without any manual intervention or updates. Usually, higher the duration of data collected, better are the outcomes as the system can then understand factors such as seasonality, shift-to-shift and operator level variations.

The application of AI is evolving and manufacturing organisations will require newer skill sets, both in operating as well as managerial positions, to implement the technology in their operations. Therefore, it is necessary to have a strong programme management and governance mechanism to ensure that change is accepted and embraced through rigorous change management initiatives.

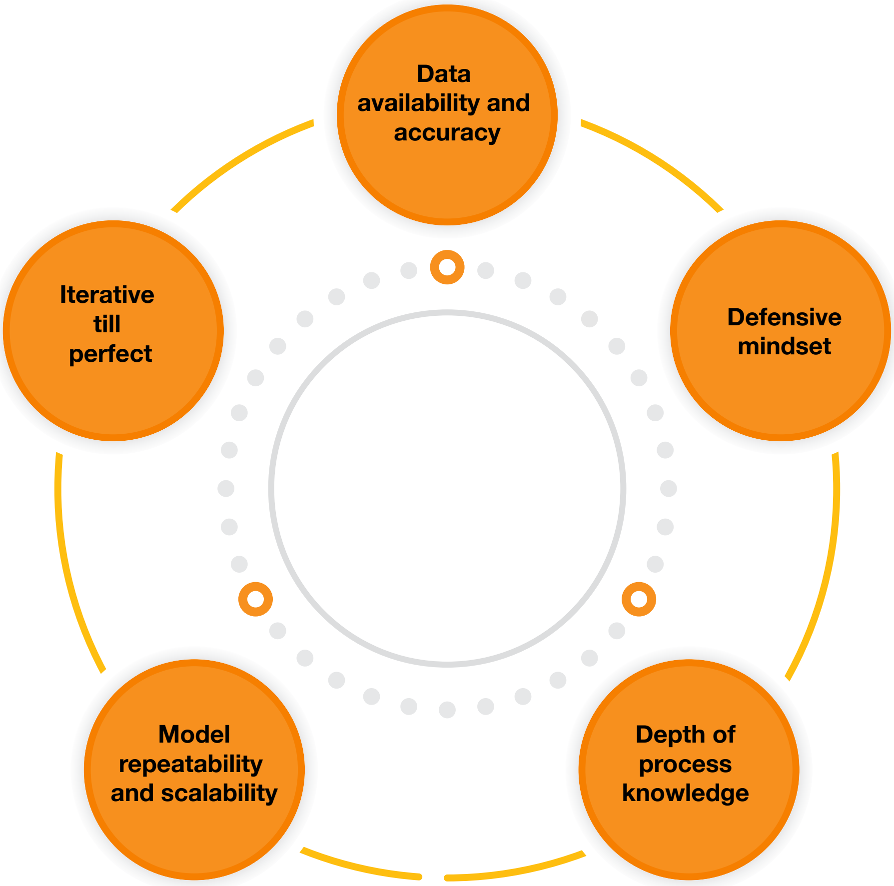
De-risking AI

The implementation of AI models has its fair share of risks. Some of the risks associated with implementing AI are:

- An AI-based model requires a lot of data for training. Mid-sized firms may not have either the systems or processes to provide quality data. As indicated earlier, granular data elements and their availability over longer periods help increase the accuracy of the model.
- The mindset of the operators is defensive as they are worried that the model will take away their control and knowledge and make them redundant. A huge amount of effort in upskilling the workforce and assurance about their role in the process is required to manage the insecurity and defensiveness of the employees through change management initiatives.
- Model quality monitoring is a function which requires deep technical understanding of the process. However, AI-based data scientists cannot develop these models without the technical knowledge of the subject. This necessitates the cooperation and collaboration among technical experts of the process and technical experts of model building for a seamless integration of AI in the process.
- Adopting an existing model to a similar use case is not straightforward and entails some complexities. Often, the parameters associated with a particular outcome are based on the manufacturing technology, age of the plant, process maturity and other factors. Therefore, in order to replicate a model for a similar operation will require a considerable amount of time and effort to rework the model and customise it for the current use case.
- Implementing AI in the operations of an organisation involves a cost component –and companies need to have patience in developing and implementing AI-based solutions. The process is iterative and the initial outcomes sometimes are suboptimal compared to what a manual process could have delivered. The more the number of iterations required, the greater are the costs involved. But AI implemented accurately can not only generate insights but also bring in huge benefits in terms of operational excellence.

The promise of AI is immense. Companies that are able to understand the prerequisites of adopting AI-based tools and direct their efforts to areas where it matters the most will be successful in the future. With experts and researchers poised to solve AI's complex problems, it's time to understand the capabilities of AI-based solutions to learn, explore and unlock new possibilities which AI has to offer.

Figure 5: Risks associated with implementing AI



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