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APPLICATION OF MODERN-DAY TECHNOLOGY INTO PROJECT MANAGEMENT PRACTICES

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ABSTRACT

Driven by emergent technological revolution, the primary purpose of this research is to explore the effect of technological transformation in the domain of project management and its potential opportunities for today's industrial and business entities. Moving from hydropower to steam power to electricity to electronics to internet and cyber space, technology has gradually evolved management theories in compared to 'Waves of Innovation'. Based on its key extracts, this paper aims to bridge the gap between technology and project management worlds by presenting an approach which industries can inherit in transforming their organizational project management practices into more tech savvy based. The research includes a comprehensive literature review carried out on six emerging technologies: AR/VR, Holography, AI, ML, IoT, 3D Printing and their impact over Project Management Key Knowledge Areas; covering potential sub-areas for technology integration, fitting technologies for each application followed by an analysis of their pros and cons. Strategically, this initiative forms a leading opportunity for industries to automate their lower-level routine tasks for effective direction of team efforts towards high level, more complex tasks including decision making and process analysis. However, the approach would also be highly controversial due to its ethical concerns in terms of cyber security and impact on existing employment models. Balancing between these two extremes involves establishing a clear set of principles and methodologies in terms of 'Strategic Organizational Transitioning' together with careful selection of technologies and its integration models based on positive Return on Investment followed by continuous employee encouragement and awareness.

Keywords: Project Management, Technology, Automation

INTRODUCTION

Managing of a project in today's digitalization world has become more complex and complicated than ever before with so much of contributors and dependencies. Analyzing of all these elements and coming to conclusions and decisions are not possible anymore by following merely traditional methods where the support and assistance from upcoming technologies are there to rescue with so many possibilities which sometimes go even beyond human capabilities and imaginations.

The concept of this research was formed primarily based on this technological advancement and its applicability into organizational project management practices to explore on how latest technology can be used in project management key knowledge areas in leveraging related aspects and thus facilitating automation.

Technology overview

The research has been performed, mainly taking into consideration the following key technologies.

i. Augmented Reality (AR)/ Virtual Reality (VR): The opportunities and gains that a business can get through an AR/VR deployment is mainly dependent on the 3D simulation that it provides which delivers a unified but an enhanced view for the user together with its ability in superimposing of information onto the user's viewpoint.

ii. Holography: Like AR/VR, the primary motivational factor for businesses in absorbing holography is the 3D projection that it is providing. But, unlike AR/VR, it is not required to use a special device or a headset in viewing of a hologram where it can be viewed by naked eye. This makes hologram to be comparatively cost effective when made available for large communities in a simultaneous manner.

iii. Artificial Intelligence (AI)/ Machine Learning (ML): Evolving from simple task automation to predictive project analytics, advice and actions, the transformation of project management with AI is supported by the fact that machines are capable of learning things by themselves instead of manually coding and feeding of every single instruction or simply acting in accordance with a pre-programmed rule set.

iv. 3D Printing: The main dimension of 3D printing influences in terms of project management is related to project procurement. Rather than waiting for months for a certain part to be manufactured and shipped from an overseas manufacturer, manufacturing locally using a 3D CAD file adds a significant saving in both time as well as cost aspects. Also, procuring based on a 3D prototype would decrease the uncertainty on company's ROI before making the purchase since it can avoid last minute surprises.

v. Internet of Things (IoT): The numerous benefits which project management can achieve by investing on IoT is mainly dependent on its key feature of providing a network of interconnected devices which can seamlessly communicate and exchange information and details in between them over internet.

Report overview

The analysis carried out on the existing literature in this report has been based on addressing of the following five key concerns.

i. Why the mentioned application is important in effectively managing a project?

ii. Where does the burden exist in traditional approach? / What makes it not suitable in today's business world to barely follow traditional methods?

iii. What is the best option that can be offered out of the technologies taken into consideration in this review?

iv. How has the industry acquired and absorbed the given technological solution? / How is the industry expected to impose the technology in their existing processes?

v. Pros and Cons which are currently visible and anticipated in using the given technical solution.

Application of technology in project integration management

The area of project integration management involves with processes and activities which can be used to identifying, defining, combining, unifying, and coordinating of various processes and activities involved with other project management key knowledge areas. Incorporation of technology in project integration management can be mainly spanned along its key application area of contract management.

Contract management

According to Rich (2018), inefficient contracting leads industries in losing between 5-40% of value on a given deal, based on the circumstances associated. In general, organizations are undertaking new projects every year which causes contract database to get its counts increased. Additionally, there exists contracts on already completed projects which need to be renewed annually. Hence, managing of contracts within a multi-project environment makes teams to go through a large volume of data by themselves on daily basis. In such case, using of manual methods based on hardcopies and softcopies at a shared folder is inefficient and adds little value. Furthermore, the number of contracts that human can review within a particular period is limited by their capacity since people are generally get distracted from external circumstances. On the other hand, going through such a large volume of data manually also impose limitations for them in processing of relevant information accurately. This concludes towards the need for teams in adhering into a more technology-based approach in managing project contracts to obtain improved results.

The biggest challenge in contract management is the sheer number of contracts that must be keep track of which are often lack uniformity and are hard to organize, manage and update (Rich, 2018). Using of an AI/ML system in this case provide options for teams to easily extract data from a large pool of contracts within an extremely little time as well as clarifying of contents in different contracts which helps for rapid contract reviewing, easing off organizing and locating of massive amounts of contract data and decrease the potential for contract disputes. As highlighted by Silverman (2019), use of ML can enhance the entire CLM cycle at three main milestones: namely (i) Contract Defining and Negotiation, (ii) Storage and Organization, and (iii) Post Contract Analysis. While the use of AI can simplify most of the areas associated with contract management, its impact will be quite evident in situations where the projects are having contracts which are with a high volume- of information and/or involves extensive negotiations with stakeholders and/or the contracts are having high-risk clauses and/or derived based on more dynamic contracting models such as 'Money for Nothing and Change for Free' etc.

Furthermore, companies who are using AI in contracting were observed with a reduction in due diligence by 80% together with a data accuracy maintained at a rate of 97% (Gorgei, 2019).

Application of AI in the context of contract management can deliver its users with better opportunities and serves them in a wide range of applications. For an example, an AI based contract management platform can identify critical obligations appear within contracts faster and with improved accuracy as well as identify different contract types even when they are in multiple languages using pattern recognition features. Furthermore, they can set automated reminders on contract renewals, extract key information from current and legacy contracts within a matter of minutes to ensure none of the key contractual data and commitments are missed and provide an all-in-one software solution to automate everything associated with contract management such as contract drafting, reviewing, redlining tracking and compliance checking etc. Solutions such as ThoughtTrace Platform, Gatekeeper AI Platform used by Ford, KAPLAN, DocuCollab's CLM solution and eBREVIA which is used by intel, TATA Power can be listed as some of such AI based platforms which can reduce manual contract review time by 30-90% and enabling tracking of contracts for its milestones with 90% less effort

(Donnelley Financial Solutions (DFIN), n.d., DocuCollab, n.d., ThoughtTrace, n.d., & Gatekeeper, n.d.).

With its ability for computers to continuously learn on things while performing the same using mathematical modeling and decision-making algorithms using available data, plentiful opportunities lie with AI/ML in the domain of contract management process (Cutright, 2018). Instead of tracking and analyzing of agreements one by one manually, using of ML algorithms can process data available in a massive document database and disclose insights and trends more accurately while AI can be configured to display potential results of a particular contract based on previous similar agreements under different scenarios which helps teams in coming up with contractual terms that enhances the contract performance during drafting phase or support in predictive identification of contracts which are under risk of underperformance or failure (Cutright, 2018). Computer Vision (CV) and Deep Learning (DL) are two areas which can assist in this context where CV helps in ensuring the contract has been signed at appropriate places and the signatures appear in the contract are matching with those on files to eliminate frauds while DL helps people mining through troves of contract to identify connections between contracts and correlation of contracts with their final outcomes (Kirkpatrick, 2019). But migrating to an AI based contract management system needs proper training mechanism to make sure its seamless adoption by teams. Since project contracts are one of the most confidential documents, data security needs to be frequently addressed by company's IT departments to ensure that the implemented solutions are sufficiently addressing the current cyber-attack issues and updates are implemented appropriately to safeguard the intra-network. Moreover, as highlighted by Cutright (2018), to attain all its benefits, AI machines should be capable of reading and processing of available data used by the system where digitalizing of the contract documents through OCR techniques is also required.

Application of technology in project scope management

Project scope management includes processes which ensure that the project is having all the required work and only the work required to complete the project successfully. As explained by PMBOK® GUIDE, managing of project scope primarily involves with defining and controlling of what is and what is not included in the project.

•Work Breakdown Structure (WBS)

Defining and agreeing upon a WBS is the key for managing of project scope which creates the basis for alternative breakdown structures such as Cost Breakdown Structure (CBS), Risk Breakdown Structure (RBS), Product Breakdown Structure (PBS), Organizational Breakdown Structure (OBS) and Functional Breakdown Structure (FBS). Since a project in general involves a huge volume of information which are being exchanged, shared, reviewed, and analyzed up to different extents by multiple stakeholders inclusive of project sponsors, technical teams, vendor teams, senior management etc., managing of such a large document and database manually would involve exhaustive efforts since project teams need to keep track of which information to be shared with whom up to which degree at which instance. On the other hand, the said approach also involves the risk of missing certain critical information which would result in missing of some key tasks and activities involved in project scope, eventually resulting for huge deviations in

the agreed upon solution and/or missing of some key business features.

Representing of key project information visually will provide a better solution in project scope management since it eases off people in identifying relationships in between different tasks and sub-tasks involves in a project. Techniques such as mind mapping in this case enable users to handle more complex projects, tackle information overload and view patterns and opportunities from the available information which is otherwise may not be visible (Frey, 2015) which makes it to stand tall amidst its peers. Integrated with Kanban boards or any other project progress reviewing technique, mind mapping will deliver project teams with better solutions in viewing of a large volume of project information in a much simpler manner and with improved understanding that helps them in deciding on way forward and prioritization of tasks/user stories, better streamlining of project work, more transparent visibility on current workflows and so far progress made, identifying, distilling, and acting upon progress backlogs and meeting project deadlines more effectively. Further highlighted by Frey (2015), mind mapping software provides its users with powerful tools in better managing their work while improving their impact and effectiveness along four basic categories as (i) Enhancement of productivity, (ii) Analysis/critical thinking, (iii) Creativity and (iv) Collaboration.

The potential value-added benefits that visual representation offers towards teams in managing of project scope has made researchers to look on possibilities of integrating intelligence into them to enhance their effectiveness. Software tools embedded with AI/ML algorithms that can effectively convert WBS into mind maps help teams in scheduling of project tasks and suggest on KPIs which ensures that the project is continuing in a healthy manner (Miller, 2019). The IBM's Watson Natural Language Understanding (NLU) AI engine used by InfoSeg can be given as an example on the captioned which analyzes large amount of data and embed them into mind maps (Frey, n.d). Further to the extraction of information available in WBS and visually representing them in a mind map, there are some other areas where intelligent based mind mapping tools would revolutionize the way teams are presenting their project related information and data. Rather than simply acting as an input device, with intelligence embedded, AI based mind mapping tools can present its users with data from external sources such as AI engines, resulting for better interpretation and manipulation as well as can also anticipate problems and issues in project timelines and fix them on behalf of the user (Frey, n.d.). In terms of project scope management, this means that team members can release themselves from manually going through different information sources such as organizational historical databases to derive WBS and identifying of issues such as scope creeps where the tool itself will do the captioned. Hence, even though sufficient evidence could not be found on commercial deployment of AI/ML in designing of mind mapping software in project management perspectives, companies are looking on opportunities that AI/ML would offer in creating of mind maps (Frey, n.d.).

Application of technology in project schedule management

Project schedule management deals with managing of project activities to ensure a timely completion of the project. While it is one of the most critical and complicated key tasks associated with a project, it has also become one of the most exhausting tasks that many of the project teams are facing in today's industrial

operational environment. Hence, more advanced and tech savvy approach is required to ensure that project stays within its defined time constraints.

•Schedule Automation

When implementing a project, managing of project scheduling would be crucial since there exists so much of interconnected and interrelated target milestones. Inaccurate schedule estimation would result in cascading of delays resulting for huge timeline deviations as well as legal concerns in some situations. Therefore, it is not just about coming up with a schedule but also to generate a schedule which use employee's time in an effective and efficient manner to come up with the maximum output within the shortest available time. Using of traditional scheduling techniques such as paper-based systems or excel spreadsheets are cheap and easy to deal with (Synerion, 2014) but become infeasible when processes getting more and more complex and complicated. With manual scheduling, it requires going through a large set of employee's personal schedules, their availabilities, application of personal leaves, overtime details etc.to prepare a high-level schedule which is having a high possibility of human errors. Furthermore, since a typical scheduling involves multiple parameters to be considered including SLAs, urgency of the job, employee personal schedules, employee skill set, external factors such as traffic, bad weather etc. (Wilson, 2019), sticking with manual scheduling techniques will not have work anymore and will generally cause either overstaffing or understaffing, affecting the health of the overall project progress. On the other hand, in the practical scenario, there can be so much sudden circumstances emerges such as unplanned machine breakdowns, team members getting sick or having urgent personal matters where manual scheduling requires managers to revisit the earlier derived project schedules and re-do the process which is not an industry best practice. Therefore, the need for automation to aid managers and team members who are responsible in scheduling has become a timely vital requirement where AI based scheduling comes into the picture.

By using AI, the scheduling software itself will draft the schedule once it is given the required parameters such as number of employees available etc. and send it to the manager for approval where manager can review, analyze, and do some modifications if needed and approve it and upon approval, the schedule will be circulated among the staff in real time and in case of sudden changes or deviations, the scheduling tool itself will regenerate a revised schedule and send for manager approval (Upadhyay, 2021). As highlighted by Upadhyay (2021), this sort of AI based scheduling tool can automate day-to-day scheduling aspect along three main areas namely (i) Optimizing resource management, (ii) Empowering field workers, and (iii) Improve customer experience where Green (2016) has highlighted four major areas where AI can make an effect in terms of project scheduling and planning aspects as (i) Real-time employee scheduling, (ii) Resource Planning, (iii) Material Planning and (iv) Detection of problems related with Scheduling. With its ability for the tool to review itself the previous schedules and learn from mistakes, AI based scheduling tools can offer project teams with better scheduling options even in complex project environments as well which will not be possible with manual methods. With its ability to extract sheer amount of data coming from different devices such as IoT sensors, RFID chips and other required data from anywhere in the value chain within a fraction of time and make use of them in making adjustments in plans in real time which is quite impossible with a human planner at

all makes AI scheduling tools to strip off most of the disruptions even before they occur and further cut-off the excess costs associated through reducing disruptions in production lines, ensuring efficient use of resources, increasing lean supply systems to reduce inventory needs and enabling planners using their time more efficiently (Hoey, 2019). Therefore, adoption of AI scheduling tools will be beneficial for project managers in many ways. But even though the approach has superlative benefits, still the adoption of AI in project scheduling are somewhat lower compared with others. The main reason behind this is due to certain limitations that are associated with AI based solutions in terms of schedule automation. Since AI systems works well if and only if the system is being fed with clean and comprehensive operational data which is the hardest in industrial setting, due to its complex nature, there involves a high cost on deployment as well. So that, integration of an AI system is confined to those who are affordable on the captioned expenses. In addition, the associated software tools will require frequent upgradations to cater the increasing demands. Also, in case of a breakdown, the procedure on recovering of lost codes and information and cost of restoring the system would be high and heavily time consuming (Reddy, n.d.). These types of factors make industries hesitating to adopt AI in their workplace environment regardless of its massive benefits.

Application of technology in project cost management

Being one of the triple constraints, managing of project cost is important in making a project success. Failure to manage projects within the allocated budget results in cost overruns and eventually the project failure. Hence, ensuring that the project is being implemented within the allocated budget throughout all its stages is crucial. In doing so, technology can be integrated under two extents: namely project cost estimation and invoice processing.

•Cost estimation

Estimation of project costs provides project teams and all involved stakeholders an idea on how much budget will be required in approximately for the project to be completed as desired. Performed poorly, the initial budget will be subjected to time-to-time deviations as the project progresses, resulting for huge project uncertainty as well as not being able to generate its anticipated ROI upon completion regardless of generating desired results in terms of its tangible deliverables. Therefore, derivation of an initial project budget estimation which is both reasonable enough and close to the actual is important to ensure that overall project expenses would be within the given budgetary thresholds. But the challenge in making such estimates in practical is that evaluations are to be done at a stage where the team members are having the least understanding and knowledge on the project and its deliverables. Hence, project teams were using multiple traditional cost estimation methods which are either analogical, analytical, or parametric over the years in making their project cost estimates as precise as possible. But, regardless of the methodology being followed, the main concern regarding these traditional cost estimation techniques is their accuracy and closeness to the real. Since project cost estimations are driven by multiple internal and external factors which are either estimator-specific or design and project specific (Elfaki et al., 2014) as well as real world business environment is associated with a higher level of psychological, political, and economic uncertainty which makes it hard to predict on future trends and resulting consequences using manual cost estimation techniques, adhering towards a

more digital approach which can consider all these factors, manage huge data volumes associated and provide efficient data analysis tools has become an emerging requirement in current project management environment.

With its ability to overcome the issues that projects are facing with traditional approaches in cost estimating, intelligent cost estimating systems based on different data analyzing algorithms such as 'Random Forest' are becoming the next industrial practice in predictive costing. In terms of project cost estimates, application of intelligence can be defined under five main categories as (i) ML systems, (ii) Knowledge Based Systems (KBS), (iii) Evolutionary Systems (ES), (iv) Agent Based Systems (ABS) and Hybrid Systems (HS) (Elfaki et al., 2014). Designed with an intelligent costing model, it is possible for teams to define their cost targets as well as save time in proposal optimization and securing and optimizing their margins on new businesses (KEPLER, 2017). There are multiple commercial software solutions that have been developed on intelligent costing such as 'easyKost' which is the first collaborative SaaS software designed for cost estimating and data mining purposes used by companies such as Accenture, Kepler, Hutchinson etc. that helps in making cost estimates 3x faster and 50% accurate (EasyKost, n.d). Additionally, a project carried out by University of Melbourne in partnership with AMP Electrical Solutions has come up with a software tool 'Intelligent Estimator' which can be used in cost estimations by construction professionals at the conceptual design stage of a building project which is more focused in cost forecasting related to power wiring, light wiring and cable pathways via exploiting building characteristics which are readily available or measurable at the early stages of a construction design (Melbourne School of Design, n.d).

In compared with traditional cost estimation techniques, integration of AI/ML eases off the project cost estimation process by allowing teams in extracting the best possible insights out of the data available within a matter of seconds. Moreover, AI tools will add value to the historical cost data which are not being precisely used in making cost estimations on newer projects and will help in providing early-stage cost advice for new projects, help in making accurate and precise cost estimations considering a wider aspect and view by integrating market conditions and economic factors, monitoring, and controlling of project costs as well as making forensic cost analysis (Sawhney & Muse, 2019). The transformation that AI tools will make on the way projects are being estimated their costs are of three forms as: (i) Classifying and Categorizing of Unclassified Cost Related Data, (ii) Developing Statistical Models for Parametric Estimating, and (iii) Identifying Reference Class Projects (Sawhney & Muse, 2019). But, since the accuracy and the quality of the output provided by an AI system is depending on the data being fed into the system, making of this effort successful requires a comprehensive and accurate collection of cost details. Since financial figures are considered as highly confidential in a general organizational scenario, receiving of financial figures from respective departments and team members will require project managers to work on balancing between the two extremes of confidentiality and process efficiency. In addition, for the intelligence cost estimation solutions to have better outcome, it is essential to focus on possibilities of acquiring of human expertise where further research needs to be carried out in finding out one integrated solution which is based on all the design and project-specific factors together with AI based cost estimation solutions being able to deliver scientific justification for

the resulting cost estimations based on real-world data by providing explanations and rationalizations as appropriate to increase the level of confidence and assist in tracing the details of the cost estimation process which enhance its level of transparency (Elfaki et al., 2014).

•Invoice processing

Living in a technological era where advancement of technology is running at its peak, nowadays, vendors are expecting their payments to be cleared almost instantly while organizations expecting their project finance teams to perform these tasks while maintaining zero errors (Laserfiche, n.d.). Hence, processing of invoices has now been transformed into a sort of balancing between accuracy and speed which makes handling of financial payments to become one of the most crucial factors that effects on project's cost management aspect. Within a general organizational scenario where multiple projects are being carried out simultaneously, finance teams must deal with a large bulk of invoices submitted by different vendors and contractors on daily basis which needs to be processed in parallel to be aligned with agreed SLAs. Hence, continuing with manual invoice processing methods by going through line-by-line in each submitted invoice on a repetitive manner and trying to process them until release of the payment in a timely manner becomes an exhausting exercise with the requirement for higher level of accuracy and precision. According to industry studies, manually handling of invoices from start to end would cost around $30-$50 per invoice where automating pieces of this process can reduce the per invoice cost by more than 30% (SoftWorks AI, n.d.).

The concept of ML can be applied in automating of invoice processing to observe and evaluate available patterns on the fed data and adjust their internal processing to produce the desired outcome. Upon submission of more invoices, system would improve its accuracy over time, continuously refining itself to reduce the gap between the systems generated outcome and the result if handled manually. According to Brooke (2019), use of AI in processing of invoices consisting of three main standard tasks as (i) Invoice OCR, (ii) Data Extraction, and (iii) Invoice Generation and can impact the invoice processing in three ways as (i) Digitalization of underlying documents and producing the invoice, (ii) Extracting of data, and (iii) Filling in data. In addition to the captioned, integration of AI/ML can further leverage associated supporting processes such as cross-checking of invoices, POs, and inventory, checking for duplicate invoices, and highlighting of ambiguous invoices to accountants for further investigations etc. where in some cases, it is possible to monitor incoming invoices in both digital and hardcopy forms either by (i) Automatically processing of invoiced submitted through an EDI platform, (ii) Flagging emails with invoices attached as PDF or an image and sending them to relevant systems for data extraction and further processing, and (iii) Scanning invoices submitted as hardcopies (Dilmegani, 2019). With its ability of extracting of information within a fraction of time, AI based invoicing solutions can reduce time that it takes on manually processing of invoices, which helps project teams in obtaining a measurable ROI within a shorter time by reducing manual processing costs, obtaining of early payment discounts, and enhancing of vendor relationships. For an example, by combining Robotic Process Automation (RPA) with AI, UiPath could automate purchase-to-pay (P2P) invoice processing at Thermo Fisher Scientific where after initial deployment, the solution operated with 82.4% accuracy rate when reading of documents together with a 70% reduction in the time that it takes on processing invoices, with about

53% of all invoices being handled straight through without any human intervention (Uipath,n.d.). Moreover, implementation of Evolution AI software solution has helped NatWest Aptimise to reduce their lead time in extracting data from invoices from 24 hours to just three seconds with the ability to handle up to 200,000 documents per day (EvolutionAI, n.d.).

AI based software tools can streamline the invoice matching and validation activities to reduce errors associated with manual methods together with automatically extracting of critical data from invoices quickly regardless of its format and identifying of any missing or incomplete data which helps teams in improving the speed and accuracy of handling invoices. The greater advantage of processing invoices using AI/ML is that since it involves minimum intervention, the captioned would subject to minimum errors whereby comparing data extracted from the current invoices with those the system has previously come across, it is possible to easily identify any discrepancies and thus improving the protection against frauds. In addition, with an AI/ML based invoice processing solution, it is possible to set automated notifications and reminders regarding key milestones associated which would eventually shorten the payment cycle and avoid late payments (Laserfiche, n.d.). However, attaining of such benefits needs to be involved with a careful analysis on the downside concerns of an intelligent invoicing solution as well. As machines are becoming more and more intelligent, powerful, pervasive, and connected, incorporating AI would increase the risk of cyber-attacks where the advancement of neural networks would broaden the type and number of possible targets and through integration of human expertise, intelligence and human labor, AI systems can generate fake data within the system which would look like they came from a reliable source and thus making attacking more easy and faster (Yao et al., 2018, p. 40-42). On the other hand, it is also important to be attentive on the impact of intelligent systems on existing employment models as well. When machines are assigned with performing of repetitive tasks, there is a potential concern that team members who were so far involved with them will lose their routine tasks which is the main resistance factor for teams in absorbing of AI/ML systems into their current practices. Therefore, it is important for project teams to make sure that the decision to go with an intelligent invoicing platform to be a positive ROI for project cost management.

Application of technology in project quality management

Project quality management includes processes for incorporating organization's quality standards with planning, managing, and controlling of project activities as well as managing of product quality requirements to meet stakeholders' expectations. The impact of technology in project quality management can be explained under the area of Quality Control/Quality Assurance (QC/QA).

•Quality Control/Quality Assurance

The process of quality inspection ensures adequate fulfillment of required quality standards by the end products/services. In terms of project quality management, it is required to ensure that all underlying processes are implemented as per the standard procedures while making the final outcomes to be aligned with the agreed quality requirements as well which includes incorporating of both organizational quality policies as well as quality standards being expected by different stakeholder teams. Moreover, in some cases, it is required to be adhered with international standards as well. Therefore, focus to be made on approaches

that assure both the associated processes as well as physical outcomes are of intended quality. Traditionally, this is done with the help of a checklist having a large set of checkpoints where the quality inspector needs to fill out this checklist prior allowing/rejecting the product for final delivery and hence the quality of the final product does not only depend on the quality of the process embraced in producing the intended outcome/s but also the level of accuracy of the inspection process being followed (Kumar, 2018). Due to its higher level of dependency on human factor as well as the exhaustive nature of the process due to its manual nature, shifting towards a more technology-based approach is essential to overcome these limitations in traditional QA/QC process.

Integrated with other advanced processing capabilities, AR in QC/QA process enables overlaying of 3D CAD data together with some extra information such as dimensional accuracy, tolerances, interference, and surface finish directly on the live video of the actual product to be inspected using an AR headset, providing an interactive platform in performing complex QA/QC tasks easily and efficiently (Kumar, 2018). With the evolution of project management approaches, today projects are being operated using teams who are even dispersed across multiple geographic locations. Executed in such a networked structure, managing of consistency in project QA/QC activities across all its locations is quite challenging with traditional manual approaches where using of AR integrated with technologies such as IoT will successfully help teams in overcoming this challenge by facilitating them in exchanging of project quality details among AR apps and thus easing off the verification and other different activities associated. Therefore, the approach has already been embraced by multiple organizations in their QA/QC activities with proven records on successful and improved results. For an example, Airbus has been incorporating 'Mixed Reality Application' or MiRA to integrate digital mock-ups into production environment, providing assembly workers to access complete 3D models of the aircrafts under production which has reduced the time required in inspecting 60,000 – 80,000 brackets in a A380 fuselage from 3 weeks to 3 days (Vita, n.d.). In Boeing, AR is used in giving team members real time instructions and interactive 3D diagrams with related to aircraft wiring processes which is considered as one of the most crucial tasks which requires the highest and the most precise accuracy and quality. With the use of traditional approaches which are based on 2D drawings, team members have to construct the image in their mind and carryout the wiring based on the created cognitive model whereby using AR, they were given a convenient approach to view the way electrical wiring needs to be arranged and continue with the activity by referring to the 3D image displayed right in front of their eyes where the approach has been evidenced with a 90% improvement in the first-time quality in against with the traditional 2D approach together with a 30% reduction in time spent on the job (Boeing, 2018). Additionally, Porsche has also tried on adopting of AR in their QA process in their assembly plant at Leipzig, Germany which could flag up any deviations beyond 0.1mm which will otherwise not be possible even with a well-trained observer and thus helps teams in deciding which vehicles pass the QA test prior being sent to the customers (KOMODO Digital, n.d.).

What makes AR to be a preferred option in project quality management in compared with traditional approaches is its ability of providing teams with a reliable and suitable approach in monitoring and ensuring of product and

process quality. With the traditional methods, ensuring of intended quality standards require team members to manually go through and review each and every component that makes up of a product and check for errors and deviations which makes it to become an exhausting exercise. By using AR in to quality assurance, companies can optimize the inspection process and thereby reducing the time consumption on verification and reducing time to market (Joshi, 2019). On the other hand, even though traditional methods are capable of catching errors, they will typically just flag the mistake or either halts the production process where AR has moved this exercise one step forward that without just flagging the mistake, it would correct the error itself or either guide the technician to the correct part or to the correct sequence (Ryznar, 2017). Moreover, by further compiling the details displayed on the AR screen into a report and sharing among stakeholders help them in easily identifying of different product errors presented and number of faulty items which then can be make use in their decision-making activities (Joshi, 2019). But achieving of all these benefits will also involve some key backlogs which industries must pay attention on. Since most of the AR applications are to be run on existing electronic devices, it is required for them to have adequate processing capabilities to run the AR applications in smooth manner as well as the expensive and technology taxing nature of AR makes developing of AR applications to become challenging for smaller businesses (Ivankov, 2019). Furthermore, using of AR compliant devices such as headsets may sometimes require basic training in which case adoption of the technology would cost the teams with additional expenses which makes integration of AR in project quality activities to be required with adequate justifications on gains over its potential drawbacks.

Application of technology in project resource management

As per PMBOK® GUIDE, project resource management deals with identifying, acquiring, and managing of resources required for successful completion of project which ensures the project is available with right resources at the right time to the project manager and the team. Integration of technology in project resource management practices can be mainly identified under the area of industrial training.

•Industrial training

When managing of project team, it is vital to ensure that members involved with different roles and responsibilities, work collectively to achieve a shared project goal. Any sort of gap between intended and actual skill level of team would result for a lag in project progress and overall project efficiency. Conducting proper training programs for team members would be a massive benefit for project managers in addressing such issues and backlogs. The conventional training practice involves trainer to be present in the training site and conduct the training program by himself. This becomes inefficient in terms of project performance since the training expert/Subject Matter Expert (SME) requires to be present in the training location physically and dedicate their time and effort whenever a training need comes within the project team. On the other hand, since team members would be involving in project work only after the completion of the training, there would be some time gap in utilizing of team resources in actual project work. Therefore, the requirement for a more tech-savvy approach was a timely requirement when it comes for industrial training.

Use of AR based training program would solve this issue by a significant amount since it elevates the way people learn by overlapping information on top of preexisting data (Lozano, 2018). By using AR in training programs and sessions, it is possible to offer the team members training on their non-familiar areas in the project without endangering individuals or damaging the equipment. Rather than hiring more experienced employees or industry experts to train the project team, AR provides the chance to provide required training anywhere at any time, based on trainee's requirement. The subjected approach is currently being executed over a wide range of applications and has been proved with extremely successful results with higher productivity. For an example, in terms of aircraft industry, Boeing has used AR in one of its training programs to guide trainees through a 50-step process subjected on assembling of an aircraft wing section which involves 30 parts. Using of AR has reduced the time that trainees were taken to complete the task by 35% than using traditional 2D drawings and documentations. Furthermore, the number of trainees who were with little or no experience could perform the operation correctly at the first attempt has increased by 90% (Porter & Heppelmann, 2017).

Other than AR, using of holography in training will help field experts in easily recreating scaled 3D images of different hardware equipment for training and display purposes which act as an optical training material. By incorporating several different images into the same hologram, trainers can give all required information at once and viewer is able to examine different parts of a device in detail by moving around the display (Pepper, 2017). As highlighted by Hackett (2013), using of holograms in industrial training is more beneficial over traditional approach due to the benefit of image strategy that it provides together with superior visual capabilities which are possible with the 3D nature of the holographic images. Due to these reasons, holography has also been a major trend among the industry over the past years in terms of conducting industrial training. For an example, with the invention of HoloLens, the Israeli army's C2 Systems Department has started using Microsoft's AR based headsets to train personnel in the field to improve overall strategy on the battlefield which also supports several other key areas such as enabling medics to perform surgeries on wounded soldiers through visual and audible instructions given by trained surgeons, monitoring troop positioning on the field from vantage points held steady by the enemy and fixing malfunctioning equipment etc. (Parrish, 2016). This enables soldiers to act efficiently and quickly in the real scenario and by blending between physical and digital worlds; hologram can provide additional information to them which they can use to make decisions when performing of tasks in real world.

In compared with traditional training approaches, using of AR and holography will benefit the projects in multiple different ways. Since it eliminates team members in frequently referring to paper manuals, they can get hands-on experience on new tasks and activities more efficiently. On the other hand, since training material can be arranged in accordance with the language preference of individual trainee, it also eliminates the language barrier that becomes problematic when it comes to traditional training (Kumar, 2018). Additionally, using of AR and holography would be an ideal solution for remote training purposes so that regardless of the physical location of the team members, required training can be provided to them. But conversely, the captioned approach will be highly challenging for small businesses due to the higher cost and advanced technology that it incorporates. On the other hand, since

most of the AR applications are based on smartphones, it is required for devices used for running and viewing AR to have adequate processing capabilities as well. Furthermore, according to the survey conducted by Perkins Coie LLP, user experience and content offerings are the topmost obstacles in mass adoption of AR within the industry due to technological limitations and glitches that exists. Since a training in general includes prompting concerns emerging during the session, designing of an AR based training becomes more challenging as all the details which needs to be distributed among newcomers needs to be included in the display video by the trainers. Therefore, it is required to consider both pros and cons when designing the most appropriate platform of AR/holography to be invaded into their day-to-day training requirements.

Application of technology in project communication management

Explained by PMBOK® GUIDE, project communication management includes processes required in ensuring timely and appropriate planning, collection, creation, distribution, storage, retrieval, management, control, monitoring and deposition of project information. Impact of technology in project communication management can be explained under the area of business meetings/distance collaboration where using technology can help teams in making their business meetings more effective and collaborative.

•Business Meetings/Distance Collaboration

While the ability to work outside the office has been a common feature within the industry over the past decades, with the COVID-19 pandemic, remote working has now become a norm where virtual reality office environments, remote collaboration and WFH (Working from Home) are going to be the future of working structure in the industrial environment (Lang, 2021). In terms of project management, while this gives rise to the requirement of managing an uninterrupted connection and collaboration among team members as if they are working within the same project environment, from the team members perspective this is further augmented with their need to getting in touch with co-workers to get to know the current status of the project and where the things are heading towards since they miss the chance of involving in 'live' conversations, backstage discussions and random meet-ups with a dispersed team architecture. Up to near recent, remote collaboration was taken place using online collaboration tools such as Skype, WhatsApp etc. which provided team members with simpler and cost-effective methods of connecting with people. But, one of the major drawbacks in them is that geographically dispersed employees sometimes find it hard to connect with each other and align with conversations and hence struggle in making effective interactions (Virtualist, n.d.) where VR emerges into the picture.

The main advantage of using VR over video conferencing and other traditional collaboration platforms relies on its facilitation for non-verbal communication which accounts for nearly 65-75% in a typical conversation (Virtualist, n.d.). With video conferencing, users find it difficult to maintain eye contact which makes him fails in understanding facial expressions, body language and related non-verbal cues of other participants. The ability of VR to create a 3D model of a person in another's virtual space helps its users in managing eye-contact easily that gives them the impression of that they are communicating with them face-to-face. Moreover, VR eliminates distractions caused by headsets which block the real world while displaying a virtual one

(Virtualist, n.d.). While the use of VR will be beneficial in multiple areas of project meetings, Johansson (2019) has highlighted some key areas where this would be with enhanced results inclusive of (i) Design Reviews, (ii) Sprint Standups, (iii) Sales Presentations, (iv) Pair Programming and (v) General Co-working. Platforms such as Spatial which is being piloted by Ford X to unify its product teams working on mobility initiatives, MeetinVR used by Volvo cars, MetaVRse in their collaborative purposes which allows its users in making presentations, reviewing 3D models, creating mind maps etc. can be pointed out as some of the most widely used examples on the captioned (Takahashi, 2018, MeetinVR, n.d.).

While video conferencing is still being used within the industry for remote collaboration and meeting purposes due to its simplicity, use of VR will facilitate better in-person simulation with its ability to manipulate 3D objects which is really beneficial in situations such as presentations and brainstorming sessions where eye-contact and face-to-face interaction is essential for effective relationship building together with the ability of connecting dispersed offices and remote workers who are out-of-office, reinforcing the concept of 'anywhere, anytime from any device'(Ashley, n.d.). Moreover, by cutting down the need for global teams to travel across to participate for business meetings, VR applications provides a cost efficient, safe, and sustainable solution for teams in managing connectivity among each other. Furthermore, by combining headsets, cameras, and other sensors to create a better collaborative virtual/ augmented environment, VR in business collaboration can provide its users with some additional functions such as walking around the projected 3D models of objects and inspect from every single angle in a collaborative environment while hosting unlimited users together (virtualist, n.d.). But even though using of VR makes it easier for teams to collaborate and interact with each other regardless of their physical location, the downside of using VR in business meetings and distance collaborative purposes is that the approach will be adding another layer in terms of digital interaction that may sometimes find it difficult for members who are not very much inclined with current technological trends and innovations as well as in some cases, the approach would probably be an overkill where in situations such as designing of some digital work for an app or website, it would be more effective and better suited to be viewed it in the actual device or deployment environment rather than reviewing it in a virtual platform (Swanner, 2019). Additionally, as argued by Kowtun (2019), many of the VR headsets that are currently in the market are still a bit bulky, pricey, and impractical as well as the provided virtual world collaboration would further isolate users by reducing real life connectivity with others. Therefore, even though the approach is with numerous benefits in compared with traditional video conferencing platforms and potential to expand further, it will not be the ideal solution in all the project communication purposes where project managers must demarcate themselves on when to use VR platforms and when to encourage physical interaction between team members.

Further to the VR, projects can also use the concept of 'Holographic Telepresence' when managing their project communication and collaboration purposes by capturing a real person in a remote location using holography and compressing the information and transmitting it over a broadband network towards a far most receiver which will then be decoded and projected using laser beam and hence, holographic telepresence provides teams with an ideal

communication method which is independent on the material format or screen type (Winimy AI, 2019). Like AR/VR, since telepresence can also provide teams with better opportunities in collaborating and connecting with employees, clients, suppliers etc. with minimum effort together with saving cost of travelling and other overhead expenses, it streamlines the project's decision-making process while facilitating for more result-oriented interactions in the meantime which makes this approach to be accepted among both small and large industries (ezTalks, n.d.). Therefore, even though the concept is at its early stages, trails deployments of holographic telepresence has already been started within the industry where airports such as Manchester and Luton's have started accommodating passengers in areas security control where travelers are informed about travel procedures such as how to prepare for the boarding, what needs to be followed in terms of security etc. and give the passengers all the information they require using holograms in order to minimize the waiting time and thus increase the performance (Digital Institute, 2014). While this eliminates the requirement for team members to be present at a particular location physically to participate in business conversations and discussions, in accordance with Winimy AI (2019), using of holographic telepresence is associated with several key challenges including (i) Requirement for light modulation in projecting holograms, (ii) Requirement for complex coding when implementing of a holographic solution, (iii) Need of carrier network with higher bandwidth and (iv) High deployment cost which makes industries to give a second though in absorbing it into their existing project management practices.

Application of technology in project risk management

Being prepared for unexpected circumstances that comes along a project's lifecycle is highly important in achieving the highest success in a project. While it helps industries to plan appropriate risks responses and assign responsibilities beforehand in such a way that it mitigates impact of negative risks, managing of risks also enhances the opportunity for positive risks. With effective risk management strategies, it can easily identify on strengths, weaknesses, opportunities, and strengths of projects where having proactive measures on dealing with potential threats as well as absorbing opportunities is one of the key driving factors towards project success (Duggan, 2019).

•Proactive risk identification

Using of traditional methods in managing and controlling of potential risks is with lower effects in today's business environment. As highlighted by Layton (2007), in most of the times, organizations only use "half a loaf" definition of risks with consideration only on threats and theories and principles are less used in exploring opportunities. On the other hand, traditional risk management techniques involve considering all potential threats and vulnerabilities based on a specific corporate environment where for industries like software which involves multiple layers of trust and risk would depend on the platform and the environment that the component exists, conventional methods would fail in addressing contextual variability of risk given changes in the core environment (McGraw, 2006). Furthermore, with traditional project risk identification, output would involve a high level of expertism, industrial experience together with a strong and all -inclusive historical database which cause project stakeholders to dedicate their time and effort explicitly on the captioned followed by frequent

reviews and updating of risk registries which makes it an exhausting activity as gathering all associated stakeholders, getting their inputs, and compiling them into a single database would involve an excessive and dedicated effort. Implemented in a complex environment where a project would be impacted with non-financial factors such as sociopolitical and macro-economic trends that shapes its way forward and create threats and/or opportunities, it is required to be come up with a more advanced approach to proactively identify of project risks and support teams in making necessary actions upon them.

While the concept of IoT would be a threat due to opening up of information to be freely available and accessed by a large community, this sort of device network with the ability to exchange data in between them without or under minimum human intervention opens teams with new ways in managing of risks in their day-to-day project activities. In terms of project risk management, with an IoT system, it is possible to provide team members with more accurate and insightful data which help them in increasing workplace safety while preventing losses in heavy industrial operations (Martin, n.d.). For an example, by using 'smart hard hat' which monitor the body temperature and heart rate of a person together with ambient temperature and humidity, it is possible to easily detect when a team member involved in a construction project is at risk of heatstroke and quickly alert him using sound and vibration notification so that risk of workplace accidents can be minimized (Martin, 2017). Furthermore, as explained by Beltramo et al. (2018), using of a sensor-based system can help teams in identifying of natural risks as well such as landslides, avalanches, floods, earthquakes, fire etc. The General Electric's Evolution Series Tier 4 Locomotive consisting of 250 sensors that generate 150,000 data points per minute helps the team in achieving enhanced safety, on time performance and higher equipment uptime in their processes (Martin, 2017) which leads them in minimizing the risk of sudden machine breakdowns upon their execution. By further integration with voice technologies, in addition to the capturing of data from one end point to another, IoT systems can enhance the way teams react in case of a risk. For an example, in terms of managing of risks such as sudden fires, fire alarm trigger panels can be configured where a single button press notifies multiple first responders such as the fire department, the hospital, and a building's property management office (Hegedus, 2017). Therefore, by balancing and optimizing multiple factors against their pre-defined thresholds in an automated manner, IoT systems are capable of managing hazardous conditions in a more effective manner that with a network of connected devices, it is possible for team members to extend this monitoring across multiple locations so that by analyzing data from multiple locations in a single dashboard, they can easy identify risks at each location one time. But, the downside of using IoT in risk identification is that implementing of such a connected network will itself create a risk since it increases the chance of company network being hacked by external parties, resulting in privacy issues where company sensitive and confidential data being uncovered and these types of concerns on security and privacy breaches together with complexity in implementing an IoT solution prevents industries from adopting IoT solutions into their organizational practices (NIC, n.d.).

Apart from IoT, another approach which can be used in project risk identification is the use of AI. As highlighted by Layton (2017), in typical risk management, risk is being analyzed in specific to a certain department such as finance department monitoring credit

risks, public relations assessing reputation risks; IT is focusing on data security risks etc. so that it results for narrow and parochial view of risks, failing in identifying the cumulative impact of risk on the project. On the other hand, since traditional risk management is heavily relying on historical data, they fail in identifying different types of macroeconomic, sociopolitical, and other megatrends including unequal levels of new regulations, advances and disruptions in technology that shapes future risk scenarios (KPMG Perspectives, 2014). In contrast, with its ability of handling and evaluating of unstructured data which do not fit neatly into structured rows and columns (Deloitte, 2016) together with the capability of computers to learn by their own using previous information on similar situations, AI can support project teams in easily uncovering the risks which are otherwise become unaware or unnoticed by human. For an example, by providing details on market behavior and developing of algorithms to continuously learn from the market reactions and reinforce their prediction and estimation accuracy and output quality, AI/ML systems help financial and project managers in quickly identifying of how the changes in market profile would impact on existing project cost management cycle where the provided insights can then be used to plan and take necessary actions to overcome the issues beforehand. With the system being fed with details of the previous projects such as planned start dates and end dates of different phases, AI is capable of assisting project team members in getting a better idea on the possible completion rate of the team and determine the likelihood of delivering the project on time (Branscombe, 2018) since in general implementation scenario, regardless of how well the project has been planned, there can be sudden external factors that cause the project schedule to get deviated from the planned which are beyond human cognitive perception. Furthermore, with its ability of learning from the previous information of similar situations by their own, AI systems can also support project teams in planning of risk response as well by suggesting of possible remedial actions.

In accordance with Layton (2017), using of an intelligent system offers team members with multiple benefits in terms of project risk management such as (i) Uplifting company's ability in identifying, assessing and taking actions on risks via enhanced collaboration, (ii) Facilitating for better strategic decision making through effective risk assessment, (iii) Reducing excessive costs and burden of risk management, and (iv) Enhancing teams in winning confidence and reassurance of stakeholders by having a more strong procedure in risk identification, analysis and management. One of the major backlogs in traditional risk management approaches is that the captioned are highly depending on people which makes them to be error prone. Since general human cognition is optimistic up to a certain level, they generally tend to see the positive path of a particular situation that they fail in rationalizing that it won't work until it is takin place in actual which causes human-based risk identification to miss certain risks. Unlikely, since decisions and outputs generated by AI systems are machine based, provided that the underlying code is error and bias free, it can uncover most of the risks as well as make better decisions than human. However, despite the benefits that AI can deliver companies in managing risks, adoption of AI itself would also become a source of risks where it is important to make suitable arrangements to mitigate and manage their impact before adoption. Due to the dependency of the resulting output of AI algorithm on nature of the data being given as input, any sort of issues related with input data will result

AI/ML algorithms in producing false output. If the underlying program is erroneous, the algorithm will not perform as expected and will give false results which may lead to serious consequences (Boillet, 2018). The risk of AI/ML solution being a target for external cyber-attacks where hackers who need confidential and sensitive data about a company can easily attack to an AI system, companies need to take continuous measures and updates simultaneous to technological advancements to safeguard the AI/ML systems form externals attacks.

Application of technology in project procurement management

Project procurement management covers processes that deals with acquiring and purchasing of necessary products, services, or results from outside the project team. Integration of technology in project procurement management domain includes application areas such as product purchasing.

•Product manufacturing/purchasing

For a successful project completion, it is vital to make sure that purchasing orders have been placed at the right time on right products. Making sure the products that are going to be delivered is mapping with the actual project requirement give project teams in having early precaution methods in preventing any sort of mismatches which would make a significant beneficial impact for the project implementations. The traditional approach of making procurements and verifying the alignment between delivered products and the actual requirement was based on 2D images drawn on a paper. While this provides a simpler method for project teams in verifying of the manufactured/procured goods, the main drawback of this approach is the absence of 3D perception of the actual equipment which makes it sometimes to miss important information by team members as well as manufacturers leading for last minute surprises and/or mismatches. Therefore, a more technological approach which is based on 3D images is required for team members to extract all necessary information before making a procurement and for the manufacture to ensure that the manufactured hardware is totally accepted by the project team. While there are multiple technologies which can produce 3D images as AR, VR, Holography, selection of a suitable approach is mainly based on the cost-effectiveness as (i) 3D modeling will be done as a one-time activity within a project lifecycle and (ii) manufacturing of project hardware equipment needs to be done at minimum cost to maintain project expenses within the defined thresholds.

The approach of 3D printing would provide the best solution in both situations since it can produce even very complex shapes and geometries in a cost-effective manner since the only prerequisite for producing a 3D printed part is a digital 3D model/CAD file. In terms of making project procurements, teams can either manufacture the required hardware components by themselves using a dedicated production team or purchase it from an external supplier in aligning with certain procurement terms and conditions. 3D printing will serve the team members in either case where it can be used in both product prototyping as well as manufacturing. Though it was initially used mainly on prototyping, today teams are moving into incorporating 3D printing methodologies into their manufacturing processes as well due to its significant benefits over reducing overall project costs and time. For an example, GE Aviation has 3D printed 30,000 Cobalt-chrome fuel nozzles for its LEAP aircraft engines by compiling several parts into a single 3D printed component that weighs 25% less and 5 times stronger through

which the company could save USD 3 million per aircraft (3dprinting, 2022). In addition, using of 3D printing, engineering team at Ford could create a brand-new mold to test a prototype engine within a 4 days' time and with a cost of USD 4,000 where the process would typically take 6 months in time and thousands of dollars in cost if proceeded with traditional standard processes (Smith, 2015). Further to the captioned, with its ability of reducing material wastage and using of exclusive materials, 3D printing further opens project teams with far better ways in managing of its overall quality as well. For an example, HRE Wheels and GE Additive in partnership has unveiled the first titanium wheel created using Electron Beam Melting (EBM) technology in 2018 under the project 'HRE3D+' where traditional manufacturing involves removing 80% of material from a 100-pound forged block of aluminum which has been reduced to 5% with 3D printing together with far stronger, corrosion resistant and light weight final product manufactured using titanium (HRE Performance Wheels, 2018).

In compared with traditional manufacturing, one of the major benefits that 3D printing can make on projects is the reduction of overall project costs. The conventional manufacturing involves with higher cost since it requires many people in the process (Tractus3D, n.d.). But since 3D modelling requires only a 3D model or a CAD file to produce an objective, it simplifies the production process of different machinery parts and products in a much cheaper and more accessible way. By dividing the entire volume of the object into smaller sub-cells using computer aided simulation tools and then filling those cells with appropriate microstructures during fabrication, 3D printing provides an ideal solution for manufacturing of customized products and complex geometries. In addition, with Fused Deposition Modelling (FDM), it is also possible to minimize waste in 3D printing compared with traditional injection-molding or casting and forging process whereas explained by Conrad (2018), whatever is designed with 3D printing has no cutting down, no leftover material and no need to reprocess the materials. On the other hand, since errors can be proactively and easily identified with 3D prototyping models, altering, and modifying it is much easier than doing it in the actual element so that once start mass production, it is possible to produce the exact one in one-go through which a project can save cost and time significantly. But validating of mechanical and thermal properties of existing materials, standardizing materials and processes on 3D printing and scaling up processes for new materials remains as challenges within the industrial context of 3D printing (Ford & Despeisse, 2016) where a 3D model or CAD file being the only requirement for 3D printing, makes anyone being able to make an object 3D printed by themselves if they have the related CAD file and a 3D printing would leads to intellectual property issues as well. Moreover, due to the low maturity of the technology, still there exists uncertainties related with product performance over extended lifespan which hinders adoption of 3D printing among the industry (Ford & Despeisse, 2016).

Application of technology in project stakeholder management

Implementing of a project in business context involves different people and teams who can impact positively or negatively. Project stakeholder management involves with identifying of these people and their impact on the project, understanding their expectations and developing appropriate management strategies for effectively engage them in project decisions and executions. In terms of project stakeholder management, the impact of technology will help providing

team members with multiple digital solutions that makes them in managing of proper communication and healthy relationship with all involved stakeholders.

•Digital Stakeholder Management

As per Tractivity (n.d.), conventional methods of stakeholder management such as letters, survey questionnaires etc. are more focused on transferring and exchanging of related information as per the general interest of the entire stakeholder group and hence addressing of each individual's personal interest is not being adequately facilitated, resulting for higher stakeholder dissatisfaction, lack of stakeholder engagement in relevant project phases, more and more concerns coming from stakeholders etc. which would eventually results in reputational damages, delayed schedules and even failing and/or cancelling of the project due to change in its objectives significantly. Furthermore, managing of stakeholders using tools such as excel spreadsheets needs a person to dedicate his time in updating and making necessary adjustments which makes things to become more complex (Hendricks, n.d.). Hence, they have become inefficient and insufficient in today's environment where focus has been emerged in shifting towards a more digital approach from traditional stakeholder management practices.

The requirement for shifting towards a digital approach in stakeholder management is further supported by the fact that with the evolution of project management practices, todays, project teams are more of a globally dispersed structure from locally centralized where keeping with touch with all involved stakeholders has become difficult with traditional methods. By introducing more and more digital channels and techniques to understand stakeholder behavior patterns, their way of thinking and how and when each stakeholder needs to be communicated and involved in project helps project teams to build up more productive and personalized stakeholder relationships. Highlighted by Kahootz (2013), transformation to digital can help teams in achieving better results in stakeholder management in three areas as (i) Informing, (ii) Consulting, and (iii) Collaborating. Hence, different solutions and options are being carried out by different industry people and researchers on optimizing and further enhancing the process of project stakeholder management where use of AI is one such option that has been incorporated over the past several years with several solutions being developed in optimizing some core aspects of project stakeholder management such as 'Simply Stakeholders', 'Stake Tracker', SMART and 'Atium'. Through integration of AI/ML, these platforms can query millions of data points available in their databases within a few seconds time and provide its users with the facility of ranking the level of stakeholder engagement which can then be used in tracking on emerging issues in a more convenient as well as a prompt manner, categorizing of project stakeholders into distinguish subgroups which makes it easy in identifying of sentient behind each stakeholder interaction and ways of establishing personalized business relationships with different stakeholders, supporting for efficient management of stakeholder interactions, communication, grievances, information and actions etc. by automatically updating and modifying of stakeholder records which helps industries in reducing their costs associated with stakeholder management by nearly 40% (Simply Stakeholders, n.d., Smart, n.d., Boréalis, n.d., TSC_ai, n.d., SustaiNet, n.d.).

However, despite its benefits offer to project managers in managing project stakeholders, using of AI having certain

limitations which prevents companies in adopting these techniques. By default, AI based solutions involve higher level of complexity where stakeholder groups from non-technical background finds it difficult to adopt. Their lack of knowledge and understanding on AI products and their offered benefits would results proposal for AI adoption to get rejected. As stated by Yao et al (2018, pp.155-157, 56–57), unfamiliarity with AI together with the huge initial capital required which makes companies to take years in achieving of its intended ROI would lead HiPPO (Highest Paid Person's Opinion) to resist on company's effort in moving towards an AI based approach. Furthermore, using of AI in an ethical approach is another key concern which needs to be considered when managing of stakeholders using AI powered system. Since solutions involve feeding of all necessary data into the AI system based on which decisions are made, there needs to be consider on the justice and fairness of derived decisions since there can be situations where the system may have ignored certain social and cultural aspects which would be considered when decisions are being made by a human being. As highlighted by Coulterman (2020), development of AI strategies and policies in aligning with socio-cultural values has become challenging over the years due to rapid changes in social, economic, environmental, and other issues. Therefore, deployment of AI in an ethical perspective needs to be addressed from different stakeholder standpoints inclusive of employees, legal teams, engineering, and product development teams to make sure the provided solutions are trustworthy and impactful (Coley, 2019).

CONCLUSION

Followed by a review on existing literature together with research on real life applications within the industry, this study explores potential application opportunities of modern-day technology into project management practices in making their performance with enhanced efficiency and effectively. Availed with multiple opportunities along its key knowledge areas, integration of technology into project management practices will opens project teams with ample number of novel opportunities where the future of project management would be a collaborative effort of both machines and people, integrated and directed towards achieving and meeting of project requirements. Gained with increased intelligence and thus mimicking the human cognitive behavior, machines will be able to provide team members with more advanced insights, recommendations and suggestions on different aspects of the project, considering both direct and indirect parameters over a wide span which are beyond human cognitive capacity where team members will be using this knowledge, integrated with their analogical, analytical and parametric thinking on identifying issues and project risks in a more proactive way and looking for ways and methods of performing project tasks in the most efficient and error-free approach. Organized in a distributed structure, team members who are geographically dispersed across multiple locations and regions will be joining together in a virtual platform where without physically attending at a particular location they can be there in multiple locations at the same time, coordinating, communicating, and sharing information with a large set of both internal and external stakeholders. Implemented with a fully automated and digitalized environment, in future project management, machines will be performing all the lower level, repetitive tasks where exploitation of project human resources will be mainly based on their cognitive capacities and competencies

involved more in planning, analyzing and decision-making activities instead of general operational work. Undergone with such a drastic revolution, the role of project manager will also be mainly shifted from acting as the facilitator between people into facilitating and coordinating between machines and people whereas stated by Pinker (2018), further to the creating of strategic value, skills, and competencies of project managers in the areas of change management, risk management as well as agile project management will be with more of use. Thus, while the technological integration would renovate the way general project management activities would be taking place within an organizational context, it will at the same time will eventually transform the job definition of project managers and team members from being valued for their technical expertism into cognitive excellency.

Anticipated with such a drastic shift in almost all the domains of project management, coping with the change will require project managers, industry experts and strategy consultants to work together with technical teams on identifying of pain points in current organizational project management practices and application of technological concepts and theories appropriately in overcoming the bottlenecks of the existing processes. Establishing of a clear set of principles and methodologies will be the core in this effort where a step-by-step change management process needs to be defined in digitalizing and automating of its internal activities to make sure the transformation is both intra and inter divisional as well as intra and inter organizational, from getting inputs within a division and generating outputs towards the same division to getting inputs from an external stakeholder organization to circulating generated outputs with other external stakeholders such as vendors, subcontractors etc. However, regardless of the technical approach that a particular organization will be adhered to in incorporating the change, all the transformational efforts are needed to be comprehensively analyzed and evaluated for their positive return on investment together with aligning with the organizational and industrial ethical framework where continuous encouragement and awareness among employees needs to be precisely followed.

REFERENCE

Rich, B. (2018). How AI Is Changing Contracts. Harvard Business Review. Available at: https://hbr.org/2018/02/how-ai-is-changing-contracts [Accessed 23 Nov. 2022].

Silverman, A. (2019). The Role of Machine Learning in Contract Analysis. contractworks. Available at: https://www.contractworks.com/blog/the-role-of-machine-learning-in-contract-analysis [Accessed 20 Nov. 2022].

Gorgei, M. (2019). Harvard Business Review Highlights How AI Is Changing Contracts. ThoughtTrace. Available at: https://www.thoughttrace.com/blog/harvard-business-review-highlights-how-ai-is-changing-contracts/ [Accessed 20 Nov 2022].

Donnelley Financial Solutions (DFIN). (n.d.). eBrevia. [online] Available at: https://www.dfinsolutions.com/products/ebrevia [Accessed 21 Nov 2022].

Docu Collab. (n.d.). The Best Contract Management Software For Business. [online] Available at: https://docucollab.com/contract-management-software/ [Accessed 21 Nov 2022].

ThoughtTrace. (n.d.). AI-Powered Document Intelligence and Contract Analytics. [online] Available at: https://www.thoughttrace.com/ [Accessed 21 Nov 2022].

Gatekeeper (n.d.). Gatekeeper - Next Generation Supplier & Contract Management. [online] www.gatekeeperhq.com. Available at: https://www.gatekeeperhq.com/ [Accessed 21 Nov 2022].

Cutright, E. (2018). AI for Contract Management: Understanding Its Potential and Limits. contractworks. Available at: https://www.contractworks.com/blog/ai-for-contract-management-understanding-its-potential-and-limits [Accessed 22 Nov 2022].

Frey, C. (2015). The Essential Guide to Getting Started with Mind Mapping Software Everything you need to know to accelerate your productivity, creativity and effectiveness at work. [online] Available at: https://mindmappingsoftwareblog.com/wp-content/9ms9/Essential_Guide_to_MMS.pdf.

Miller, D. (2019). How are AI and Bots Changing Project Management. Nozbe. Available at: https://nozbe.com/blog/how-ai-will-change-pm/ [Accessed 11 Nov. 2022].

Frey, C. (n.d.). AI & Mind Mapping Soft ware How natural language processing, deep learning, intelligent agents and image recognition will revolutionize visual thinking The Mind Mapping Software Blog. [online] Available at: http://mindmappingsoftwareblog.com/wp-content/mms-ai/AI-and-Mind-Mapping-Software-Report.pdf.

Synerion (2014). The Pros and Cons of Current Employee Scheduling Methods. [online] Available at: https://blog.synerion.com/your-guide-to-creating-an-employee-schedule [Accessed 11 Nov. 2020].

Green, P. (2016). Real-Time Artificial Intelligence for Scheduling and Planning Make-to-Order Manufacturing. [online] industrytoday, BellHawk Systems Corporation, pp.1–10. Available at: https://industrytoday.com/wp-content/uploads/2016/11/real-time-ai-make-to-order-whitepaper.pdf [Accessed 11 Nov. 2022].

Upadhyay, A. (2021). Scheduling Optimization Got You Down? AI Is the Way to Go. Insights. Available at: https://lab.getapp.com/scheduling-optimization-with-artificial-intelligence/ [Accessed 11 Nov. 2022].

Hoey, B. (2019). 5 Facts About AI in Production Planning. flexis. Available at: https://blog.flexis.com/5-facts-about-ai-in-production-planning [Accessed 12 Nov. 2022].

Reddy, K. (n.d.). Artificial Intelligence Advantages and Disadvantages. wisestep. [online] Available at: https://content.wisestep.com/advantages-disadvantages-artificial-intelligence/ [Accessed 12 Nov. 2022].

Elfaki, A.O., Alatawi, S. and Abushandi, E. (2014). Using Intelligent Techniques in Construction Project Cost Estimation: 10-Year Survey. Hindawi-Advances of Civil Engineering, Available at: http://downloads.hindawi.com/journals/ace/2014/107926.pdf [Accessed 12 Nov. 2022].

Kepler (2017). Algorithms and Artificial Intelligence: New Horizons for Cost Estimation and Modeling?. [online] Available at: https://www.kepler-consulting.com/en/articles/cost-modeling-algorithms/ [Accessed 12 Nov. 2022].

Easy Kost. (n.d.). Product Costing Software For Manufacturing. [online] Available at: https://www.easykost.com/solutions/product-costing-software [Accessed 12 Nov. 2022].

Melbourne School of Design. (n.d.). Intelligent Estimator. [online] Available at: https://msd.unimelb.edu.au/research/projects/completed/intelligent-estimator [Accessed 13 Nov. 2022].

Sawhney, A. & Muse, A. (2019). Can AI transform the way we estimate construction projects? [online] Planning, BIM & Construction Today. Available at:

https://www.pbctoday.co.uk/news/bim-news/ai-construction-estimates/59477/ [Accessed 15 Nov. 2022].

Laserfiche. (n.d.). Why You Should Use AI for Invoice Processing. [online] Available at: https://www.laserfiche.com/ecmblog/why-you-should-use-ai-for-invoice-processing/# [Accessed 15 Nov. 2022].

Soft Works AI. (n.d.). Automated Invoice Processing – Softworks AI. [online] Available at: https://swordersystem.com/our-solutions/automated-invoice-processing/ [Accessed 16 Nov. 2022].

Brooke, S. (2019). How Can Invoice Processing Benefit from Artificial Intelligence? [online] Becoming Human: Artificial Intelligence Magazine. Available at: https://becominghuman.ai/how-can-invoice-processing-benefit-from-artificial-intelligence-d557c440d8c [Accessed 16 Nov. 2022].

Dilmegani, C. (2022). In-depth Guide to Automating Invoice Processing [online] AIMultiple. Available at: https://research.aimultiple.com/invoice-automation/ [Accessed 16 Nov. 2022].

UiPath. (n.d.). Document Understanding Reduces Thermo Fisher Scientific's Invoice Process | UiPath. [online] Available at: https://www.uipath.com/resources/automation-case-studies/document-understanding-reduces-thermo-fisher-scientific-invoice-process [Accessed 20 Nov. 2022].

EvolutionAI. (n.d.). Evolution AI data extraction from invoices for NatWest Aptimise. [online] Available at: https://www.evolution.ai/case-studies/natwest-aptimise [Accessed 20 Nov. 2022].

Yao, M., Jia, M. and Zhou, A. (2018). Applied Artificial Intelligence. United States of America: TOPBOTS Inc., pp.155-157,56–57,40-42,85.

Kumar, S. (2018). Have You Heard? Augmented Reality In Manufacturing Is a Part of Industry 4.0 Revolution. Learn These 5 Successful Ways | Augrealitypedia. AugRealityPedia (ARP). Available at: https://www.augrealitypedia.com/augmented-reality-manufacturing/ [Accessed 16 Nov. 2022].

Vita, A.D. (n.d.). Six applications of AR in Manufacturing. [online] Appearition. Available at: https://www.appearition.com/six-applications-of-ar-in-manufacturing/ [Accessed 17 Nov. 2022].

Boeing.(2018). Boeing: Boeing Tests Augmented Reality in the Factory. [online] Available at: https://www.boeing.com/features/2018/01/augmented-reality-01-18.page.

Komodo Digital (n.d.). Augmented Reality (AR) Use Within Manufacturing. [online] KOMODO Digital. Available at: https://www.komododigital.co.uk/insights/augmented-reality-ar-use-within-manufacturing/#:~:text=Porsche [Accessed 17 Nov. 2022].

Joshi, N. (2019). How AR can ensure quality control in manufacturing. Allerin. Available at: https://www.allerin.com/blog/how-ar-can-ensure-quality-control-in-manufacturing [Accessed 17 Nov. 2022].

Ryznar, P. (2017). How Augmented Reality is Improving Quality Assurance Measures for Manufacturers. Light Guide Systems. Available at: https://www.lightguidesys.com/resource-center/blog/how-augmented-reality-is-improving-quality-assurance-measures-for-manufacturers/ [Accessed 18 Nov. 2022].

Ivankov, A. (2019). Advantages and Disadvantages of Augmented Reality. PROFOLUS. Available at: https://www.profolus.com/topics/advantages-and-disadvantages-of-augmented-reality/ [Accessed 18 Nov. 2022].

Lozano, J.-C. (2018). What Augmented Reality Training Is And How To Leverage It In Your L&D Process. EMERGING TECHNOLOGIES. Available at: https://elearningindustry.com/what-augmented-reality-training-is-leverage-ld-process [Accessed 18 Nov. 2022].

Porter, M.E. and Heppelmann, J.E. (2017). Why Every Organization Needs an Augmented Reality Strategy. Harvard Business Review, [online] (November-December 2017). Available at: https://hbr.org/2017/11/a-managers-guide-to-augmented-reality [Accessed 19 Nov. 2022].

Pepper, A. (2017). Five surprising ways holograms are revolutionising the world. The Conversation. Available at: https://theconversation.com/five-surprising-ways-holograms-are-revolutionising-the-world-77886 [Accessed 19 Nov. 2022].

Hackett, M. (2013). Medical Holography for Basic Anatomy Training. In: . [online] Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC). p.8. Available at: http://cdn2.hubspot.net/hub/151303/file-476620026-pdf/docs/medical_holograms_whitepaper.pdf?t=1470855027075 [Accessed 19 Nov. 2022].

Parrish, K. (2016). Israel using Microsoft's HoloLens to help soldiers on battlefield, train personnel. DIGITAL TRENDS. Available at: https://www.digitaltrends.com/virtual-reality/israel-army-microsoft-hololens-battlefield-training/ [Accessed 19 Nov. 2022].

2018 Augmented And Virtual Reality Survey Report Industry Insights Into The Future Of AR/VR. (2018). [online] Available at: https://www.perkinscoie.com/images/content/1/8/v2/187785/2018-VR-AR-Survey-Digital.pdf

Lang, B. (2021). 27 VR Apps for Remote Work, Education, Training, Design Review, and More. roadtovr. Available at: https://www.roadtovr.com/vr-apps-work-from-home-remote-office-design-review-training-education-cad-telepresence-wfh/ [Accessed 21 Nov. 2022].

Virtualist. (n.d.). How VR collaboration software can improve your business meetings? [online] Available at: https://virtualist.app/how-vr-collaboration-can-improve-your-business-meetings/ [Accessed 21 Nov. 2022].

Johansson, N. (2019). VR For Remote Meetings: The Ultimate Guide. [online] XR4work. Available at: https://medium.com/xr4work/vr-for-virtual-meetings-the-ultimate-guide-d0c9ebe634d4 [Accessed 21 Nov. 2022].

MeetinVR (n.d.). MeetinVR - Business Meetings & Collaboration in VR. [online] MeetinVR. Available at: https://www.meetinvr.com/smb/ [Accessed 21 Nov. 2022].

Takahashi, D. (2018). Spatial raises $8 million for augmented reality collaboration platform. [online] Available at: https://venturebeat.com/business/spatial-raises-8-million-for-augmented-reality-collaboration-platform/ [Accessed 21 Nov. 2022].

Ashley, S. (n.d.). 3 Ways VR Technology Will Transform Your Business Meetings. [online] Available at: https://www.pgi.com/resources/articles/3-ways-vr-technology-will-create-better-meetings/ [Accessed 21 Nov. 2022].

Virtualist. (n.d.). How VR collaboration software can improve your business meetings? [online] Available at: https://virtualist.app/how-vr-collaboration-can-improve-your-business-meetings/.

Swanner, N. (2019). Augmented Reality Collaboration Is Real. Avoid It Like the Plague. dice. Available at: https://insights.dice.com/2019/01/25/augmented-reality-collaboration/ [Accessed 22 Nov. 2022].

Kowtun, A. (2019). Council Post: How Virtual Reality Could Change The Way We Work. [online] Forbes. Available at: https://www.forbes.com/sites/forbesbusinessdevelopmentcouncil/2019/01/24/how-virtual-reality-could-change-the-way-we-work/?sh=2edd7303595b [Accessed 22 Nov. 2022].

Winimy AI (2019). Challenges in bringing Holographic Telepresence Technology to the masses. [online] Medium. Available at: https://becominghuman.ai/challenges-in-bringing-holographic-telepresence-technology-to-the-masses-91e5742d7faf [Accessed 22 Nov. 2022].

www.eztalks.com. (n.d.). Main Benefits of Telepresence for Business Organizations | ezTalks. [online] Available at: https://www.eztalks.com/video-conference/main-benefits-of-telepresence-for-business-organizations.html [Accessed 22 Nov. 2022].

Digital Institute (2014). In: Holograms and telepresence. [online] Available at: https://www.institut-numerique.org/2-holograms-and-telepresence-52d0f22a3c782 [Accessed 22 Nov. 2022].

Duggan, T. (2019). Why Is Risk Management Important to Project Success? Small Business. Available at: https://smallbusiness.chron.com/risk-management-important-project-success-56920.html [Accessed 23 Nov. 2022].

Layton, M. (2007). Traditional Risk Management Inadequate To Deal with Today's Threats. Expert Commentary. Available at: https://www.irmi.com/articles/expert-commentary/traditional-risk-management-inadequate-to-deal-with-todays-threats [Accessed 23 Nov. 2022].

McGraw, G. (2006). The Role of Architectural Risk Analysis in Software Security. informIT. Available at: https://www.informit.com/articles/article.aspx?p=446451&seqNum=6 [Accessed 23 Nov. 2022].

Martin, J. (2017). How the Internet of Things is transforming risk management. Available at: https://www.airmic.com/news/guest-stories/how-internet-things-transforming-risk-management [Accessed 23 Nov. 2022].

Beltramo, R., Cantore, P., Vesce, E. and Bernardi, S.M. and P.D. (2018). The Internet of Things for Natural Risk Management (Inte.Ri.M.). Perspectives on Risk, Assessment and Management Paradigms. [online] Available at: https://www.intechopen.com/books/perspectives-on-risk-assessment-and-management-paradigms/the-internet-of-things-for-natural-risk-management-inte-ri-m- [Accessed 23 Nov. 2022].

Hegedus, N. (2017). How to make the IoT better with voice. ERICSSON BLOG. Available at: https://www.ericsson.com/en/blog/2017/8/how-to-make-the-iot-better-with-voice#:~:text=One%20of%20the%20clearest%20use,fire%20alarm%20emergency%20call%20systems.&text=The%20technology%20to%20enable%20these,is%20already%20starting%20to%20emerge. [Accessed 23 Nov. 2022].

NIC (n.d.). Internet of Things for Businesses | Learn the Benefits & Risks | NIC. [online] www.nicitpartner.com. Available at: https://www.nicitpartner.com/risk-benefits-internet-things-businesses/ [Accessed 23 Nov. 2022].

KPMG Perspectives. (2014). Systemic risk: A limitation of traditional risk-management practices. BusinessMirror. [online] 12 Oct. Available at: https://businessmirror.com.ph/author/kpmgperspectives/ [Accessed 23 Nov. 2022].

Why artificial intelligence is a game changer for risk management. (2016). [online] Available at: https://www2.deloitte.com/content/dam/Deloitte/us/Documents/audit/us-ai-risk-powers-performance.pdf.

Branscombe, M. (2018). How AI could revolutionize project management. CIO. Available at: https://www.cio.com/article/3245773/how-ai-could-revolutionize-project-management.html [Accessed 23 Nov. 2022].

Boillet, J. (2018). AI: a risk and a way to manage risk. Ernst & Young Global Limited, pp.1–3.

3dprinting (n.d.). What is 3D printing?. [online] 3D Printing. Available at: https://3dprinting.com/what-is-3d-printing/.

Smith, R. (2015). 7 Ways 3D Printing Is Already Disrupting Global Manufacturing. Forbes. Available at: https://www.forbes.com/sites/ricksmith/2015/06/29/7-ways-3d-printing-is-already-disrupting-global-manufacturing/#603a1ce01c0f [Accessed 23 Nov. 2022].

HRE Performance Wheels. (n.d.). HRE Wheels Partners with GE Additive to Create First 3D-Printed Titanium Wheel.

[online] Available at: https://www.hrewheels.com/news/hre-wheels-partners-with-ge-additive-to-create-first-3d-printed-titanium-wheel#.Xx5tpp4zbIU [Accessed 23 Nov. 2022].

Tractus3D. (n.d.). 3D Printing in Manufacturing. [online] Available at: https://tractus3d.com/used-by/manufacturing.

Conrad, G. (2018). How 3D Printing is Impacting Manufacturing. Manufacturing Tomorrow. [online] 22 Mar. Available at: https://www.manufacturingtomorrow.com/article/2018/03/how-3d-printing-is-impacting-manufacturing/11190/ [Accessed 25 Nov. 2022].

Ford, S. and Despeisse, M. (2016). Additive manufacturing and sustainability: an exploratory study of the advantages and challenges. Journal of Cleaner Production, 137, pp.1573–1587.

Joshi, N. (2019). 3 ways augmented reality can transform warehouse management. Allerin. Available at: https://www.allerin.com/blog/3-ways-augmented-reality-can-transform-warehouse-management [Accessed 26 Nov. 2022].

Tractivity (n.d.). Shortcomings Of Traditional Stakeholder Management. [online] Available at: https://www.tractivity.co.uk/blog/stakeholder-management-shortcomings [Accessed 26 Nov. 2022].

Hendricks, A. (n.d.). Stakeholder Management system features. Simply Stakeholders. Available at: https://simplystakeholders.com/stakeholder-management-system/ [Accessed 26 Nov. 2022].

Kahootz. (2013). Building on traditional stakeholder engagement methods. [online] Available at: https://www.kahootz.com/building-on-traditional-stakeholder-engagement-methods/ [Accessed 26 Nov. 2022].

Simply Stakeholders. (n.d.). How It Works. [online] Available at: https://simplystakeholders.com/how-it-works/ [Accessed 26 Nov. 2022].

SMART. (n.d.). SMART - Intelligent stakeholder management software. [online] Available at: https://smart.syrenis.com/index.html/ [Accessed 26 Nov. 2022].

Boréalis. (n.d.). Boréalis | Stakeholder Engagement Software, and More. [online] Available at: https://www.boreal-is.com/ [Accessed 26 Nov. 2022].

TSC_ai (n.d.). TSC The Stakeholder Company. [online] TSC The Stakeholder Company. Available at: https://tsc.ai/ [Accessed 26 Nov. 2022].

SustaiNet Solutions Stakeholder Information Managment Solutions. (n.d.). [online] Available at: https://www.sustainet.com/wp-content/uploads/SustaiNet-StakeTracker-Brochure.pdf [Accessed 26 Nov. 2022].

Coulterman, A. (2020). Ethical AI: why and how it needs to work with communities. Medium. Available at: https://becominghuman.ai/ethical-ai-why-and-how-it-needs-to-work-with-communities-a1c1d717168f [Accessed 26 Nov. 2022].

Coley, J. (2019). Mapping Your Organizations Internal Stakeholders For AI Ethics Success. GENESYS. Available at: https://www.genesys.com/blog/post/mapping-your-organizations-internal-stakeholders-for-ai-ethics-success [Accessed 26 Nov. 2022].