DIGITAL PROJECT EXECUTION – OPTIMIZING YOUR ASSETS

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Abstract – Database design tools, which are becoming more and more common, deal with projects from the conceptual level through to the final design phase. The structure determines the useful & relevant information which is to be captured as well as how it is to be maintained, formatted, conditioned, and transferred across the enterprise. The success of a digital project execution hinges on adopting the correct approach, capturing relevant information, and transferring it with minimum effort.

This paper will look at the benefits of classifying, capturing and storage of the relevant information for the project in a digital format and transferring this data from conceptual design stage through to plant operation and maintenance with minimum effort. In addition, the paper will discuss the tool level integration required for optimal project execution and identify key areas of improvement when preparing the stage for digital twins.

The project which will be used as an example is a large energy project. These projects often face opposition due to a lack of credible supportive data from past projects which are now existing installations.

Key words – Digital projects, Digital twins, Digital assets, Database design tools, and Design tool integration.

I. INTRODUCTION

For the Process, Chemical, Oil & Gas industries, one of the primary objectives in recent years has been to optimize production. There are numerous reasons for this focus ranging from the volatility of oil prices to environmental and political pressures. Information was seen as a primary means by which this goal would be realized. Carbon capture is a recent addition which adds to the production efforts since recording emissions and carbon capture must be strictly monitored and provided as proof of environmental compliance.

Approximately 10 years ago, there was an industry wide initiative to obtain more data. The result was a massive increase in data; however, the vast majority of this data was raw, cumbersome and time consuming with little benefit to the enterprise. [1] In order for this data to be useful, it must be actionable which requires the application of knowledge and use of formatting to make it understandable.

Actionable information must be obtained from the enterprise to achieve the ongoing adjustments, improvements, and optimization necessary to do so. This information comes from the integration of OT and IT platforms. OT was considered a sacred system and neither IT nor IM policies were applicable for implementation on OT network. With more and more OT and IT integration, it is our opinion that engineering should be responsible for evaluating the risk assessments for the level of integration between these two platforms.

In today's world, decision making is driven by data collected from various sources, plant management is no different. These data points are well defined in the plant engineering phase; the plant engineering team, licensors, vendors, manufacturers, and other stake holders determine the data sets and attribution level details. However, when it comes to who absorbs and maintains data at the plant level for operation, maintenance, and reporting purposes, the delineation of dataset and attribute level details are so widely interpreted that the final dataset is either too expansive, or too little information is reported. In most cases, the former is applicable where too many strings are attached to one object while pulling data from operating software. This not only makes the application cumbersome but also renders it a high resource user and more susceptible to cyberattack.

In recent years, the authors have been involved with a number of IT/IM activities ranging from plant engineering to construction, commissioning, and the transfer of data for plant operation. An example of excessive data occurred when the client requested an object level dataset that might be required only for construction purposes for inclusion in the operational database. On the other end of the spectrum, an example of too little data is the case where the client requirements include minimal or no IT/IM objectives and miss key elements which would prove beneficial in the end. A specific example here is a case where ambient temperatures and converter operating temperatures were not incorporated in the dataset; information which would have proven useful on several occasions to troubleshoot system issues and limitations.

Balance is required on either end to utilize the available data for improving overall plant efficiency vs. developing cumbersome applications which burden the system unnecessarily. It is interesting to note that the cumbersome applications are not only heavy on IT system resources, but they also make the application more vulnerable to cyber-attacks due to the size of the dataset associated with the object.

Database design tools have the added benefit that they help to establish a common mindset as well as the right approach for new projects while maintaining a clear end target with minimal deviations from the goal.

II. THE BENEFITS OF IT / OT INTEGRATION

Electrical equipment, control systems and the electrical industry itself have developed over time due to the independent and uncoordinated efforts on the part of many individual contributors. There was also, at one point in design, a philosophy to establish proprietary and unique networks to secure a commercial advantage for some manufacturers in an effort to secure future business. As a result, the integration of electrical equipment and the associated control systems which go into a facility is not a simple task and requires technical innovation to realize improvements. Industrial operations have seen radical changes in the last several years. These changes resulted from the combination of several technologies which, in turn, are driving the latest trends in the electrical industry and a change in attitude with respect to combining technologies for the best result.

The foundation upon which the Internet of Things (IoT) for industrial motor control is built are the advances in intelligent motor control and field devices coupled with a common control network based on several potential platforms including but not exclusive to Ethernet communications. This basic integration was the starting point [2]. Further to this, cloud technology, developments in control software, and, more recently, edge computing are driving the future of modern manufacturing. A common communication platform provides many benefits which are realized with the integration of intelligent motor control and field devices into an automation control system technology and shared device profiles to reduce the time, effort and cost of initial integration and total cost of ownership over the life of the system. There are numerous benefits when the operational technology in industrial processes adopt a plug and play approach including the fact that it aligns industry with the technologies that surround us in our personal everyday life today; we do not have to retrain or minimize the replacement of legacy equipment and systems.

The Internet of Things (IoT) is worldwide and transforming manufacturing operations everywhere. It is helping to level the playing field by reducing regional advantages such as inexpensive labor. This is pivotal as our global economy attempts to recover from the effect of COVID and associated material and labor shortages.

The Industrial Internet of Things (IIoT) is the application of these connecting technologies (IoT) in factories and process facilities leading to a new level of efficiency, reliability, agility, and performance. IIoT offers manufacturers new business opportunities, cost savings and improved machine monitoring and maintenance as well as many other benefits.

A. Manufacturing Optimization:

A manufacturing process enabled with sensors and managed with IIoT systems can monitor process conditions, equipment status and workflows for optimal output.

B. Product Quality:

The ability to address production problems immediately and reduce downtime, minimize lost productivity and product defects is a benefit of IIoT. Further to this, finished products can be measured and tested.

C. Production Monitoring:

Constant communication between systems and machines ensures optimal throughput and minimal defects are identified in real-time.

D. Inventory Management:

Data, analytics, insights, and other related intelligence allows inventory systems to run seamlessly by providing accurate real time estimates of available material and work-in-progress.

E. Supply Chain Management:

Monitoring upstream sources feeding the process to provide proactive knowledge of potential shortages.

F. Predictive Maintenance:

Historically, it has been accepted that most equipment and system failures occur without notice or warning. This is being challenged due to the associated costs of an unplanned outage which easily supports investment in new IIoT, preventative maintenance technology which incorporates analytics to predict machine failures.

G. Order Tracking:

Production systems equipped with the necessary sensing make it possible to report on near real time progress of orders and customer usage.

H. Energy Management:

Industrial manufacturing consumes more than half of the world's electricity. The use of IIoT to track production versus energy consumption will increase energy efficiency.

I. Service:

The scheduling and oversight of field service, repair parts, etc. in all forms are facilitated by an automated database enabled system. A well-designed system provides actionable data needed to stock spare parts, schedule PM and the staff required to do so. The tools provided by IIoT facilitate data visibility which in turn optimizes the maintenance spend for reliability.

Most if not all organizations are moving toward digital technologies to varying degrees more than ever before because of the aforementioned benefits and many more. As companies approach the challenges associated with combining legacy and new digital technologies and processes, many are struggling to integrate the two due to the many disparities that exist in today's industrial environment. This results in interruption of operations, safety issues and security risks.

Faced with these challenges, organizations can choose to overcome the issues internally with their limited resources or they can engage external partners to bring new perspectives which may allow things to evolve more readily. External providers often are needed in order to bring the right and most up to date skillset to build and maintain data systems. These are highly skilled and specialized individuals, and if an end user only needs 1 or 2 of them, there isn't human redundancy if one isn't able to work any longer. The additional resources and skills can accelerate progress on the journey to digital-first operations due to their wider industrial visibility and experience. They have seen what works and what issues arise across many industries and situations if they are a neutral and trusted third party as organizations seek to align to a common strategy. With more extensive technical abilities than an individual end user organization can support internally, the right partner can present examples of other installations worldwide which have streamlined operations and processes.

Examples where an external resource can help to overcome in house limitations and internal obstacles such as existing mindsets are:

Industry wide exposure not simply individual corporate best practices. What are other end users in the same industrial space doing to overcome operational and historical business issues? Having seen a wider variety of situations and environments gives these providers a better opportunity to avoid common pitfalls and failures. They will understand best practices based on what others have tried.

Alignment on a common approach. An external partner is more likely to be seen as an unbiased third party. This can help to maintain a vision of the big-picture which is to promote more efficient and effective overall operation rather than to focus on specific departmental goals.

Address technical gaps and limitations. Equipment has become more advanced and complex making it difficult for a small team to cover all the bases.

Automated integration helps suppliers, integrators, electrical procurement consultants (EPC's) and end users to reduce time and costs throughout the lifecycle of the equipment. The savings in cost and time begin with engineering, continue through to commissioning and start-up as well as the long-term operation of the equipment. These improvements are realized due to factory testing, increased accuracy in terms of programming and tagging, improved troubleshooting and many other benefits associated with the approach. Furthermore, the data that a system with more comprehensive integration brings to the application is invaluable. Integration is the necessary foundation upon which data aggregation is made possible. As discussed in a previous paper, the more accurate term to use might be information as opposed to data [1]. Information enables condition-based monitoring, troubleshooting and predictive maintenance. Recent developments and enhanced capabilities that are being realized are leading us to question past attitudes and accepted practices in the workplace in many areas including safety, commissioning, unexpected failures, and maintenance strategies to name a few of the items being challenged. This is because it is becoming possible and practical to do things which were not feasible before. Manufacturers are now implementing enhancements such as predictive and prescriptive maintenance, artificial intelligence, and virtual reality to name a few examples.

The recent pandemic has changed the world forever particularly in the areas of remote connectivity, supply chain and the impact of the media and social networking. The need to isolate and social distance to prevent the spread of disease has accelerated our ability to work and communicate remotely. Before COVID, this was already an industry focus and direction. If this had not been the case, the impact on the world would have been even more devastating.

Another major issue is the numerous supply chain challenges which have surfaced demonstrating just how fragile the "global" supply network has become. This is causing many to question the present supply chain strategy including our dependence on offshore manufacturing and transportation logistics. There are currently initiatives to "near-shore" production rather than rely on China to secure supplies and avoid / reduce transportation costs that can be realized with recent technology. To realize improvements, it is important to drive inefficiencies out of manufacturing and business processes. Businesses must become much more agile to address the current volatility being seen in the world market. Some of this volatility is related to the media, both social and the news. The influence this has had in changing public opinion and behaviour has been dramatic in some cases changing market demand overnight which in turn has led to major swings in price and lead times.

Many industries are already struggling with an aging workforce which is retiring faster than capable personnel can be brought on board to replace them. This makes it essential to capture and leverage their expertise before it is lost particularly in the case of legacy systems and equipment which have evolved over time, may not function with modern communication protocols and in many cases are simply obsolete.

Extending the life and ensuring supply of current producing assets is one of the primary objectives for oil and gas operators particularly under the current economic conditions. Reducing costs to stay competitive in the energy market is another major industry challenge. Optimizing production on currently operating sites is therefore a priority for oil producers. Maximizing production efficiency, reducing extraction, and refining costs have been at the forefront for a few years now. However, the economic climate has changed dramatically even since the start of this paper. Due to the war in Ukraine and other immediate economic conditions, oil and gas prices have increased substantially due to sanctions and other contributing factors, so exploration and new facilities are now back in the budget; but for how long?

Even with the current price revival, developing new sources of supply is becoming more difficult and expensive due to increased regulations. Environmental pressure due to the current negative public perception of the O & G industry has caused many operators not to invest in new production facilities and move to renewables which requires capital from their existing assets. End users are focusing on achieving high reliability without unplanned shutdowns to achieve highest throughput with their existing facilities and assets to fund their new investments. This requires extensive information and a knowledgeable workforce. Regardless of the immediate economics, we have seen circumstances change quickly and dramatically and can expect this to continue. It is and will become increasingly important to be agile and adaptable to survive.

The other item to address is the gap between production and the front-end information (IT) aspects of the enterprise. See Fig. 1. Many organizations have gone through an enterprise resource planning (ERP) software implementation to achieve a better collaboration between their various business systems. Despite these efforts, human intervention has still been required to bridge the gaps between many out-of-date legacy systems. The human effort required would be better utilized to improve the process rather than to continually patch it [2].

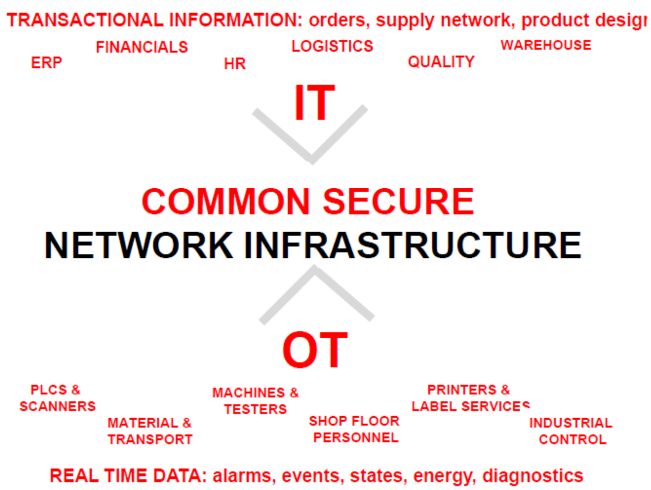

Fig. 1 IT / OT Convergence

Many industries have begun their digital transformation journey. This is at a time when digital transformation is still being defined. There are multiple new targets which can be realized with the extensive data that is realized from integration. Analytics and artificial intelligence are the next levels for which industry is reaching. The promise of reduced down time, optimizing production and other benefits justify the efforts applied in these areas.

Another consideration is the designing of the plant of today and making it flexible to remain viable for the longer term. Technology is changing so rapidly, how does a plant that is being designed today and constructed over the next few years cope with the accelerating pace of technology? How state of the art will it be 20 years after commissioning or longer?

Evolution of software design tools – From visual graphics to data driven design tools where each object needs attribution for a purpose is one means by which to achieve consistency and long term sustainability of the facility.

III. ANALYTICAL VS DESIGN SOFTWARE

For a green field plant, the design development, design validation and calculations are carried out at different stages using software databases. The software databases can be classified in three major categories (1) Analytical software, (2) Design software, and (3) Commercial spreadsheets. Of these three classifications of software, the first two are often proprietary software with front end and back-end utilities. The commercial spreadsheet solution may be either available as freeware or developed by individual contributors for consistent & accurate calculations.

The analytical software is used to assess electrical equipment performance, equipment sizing and for safety evaluation. This software is very helpful for managing the electrical performance of the system and equipment. The equipment attribution details are drawn from a large available library built within the software for calculations. See Fig. 2 for a working example. The analytical results are scenario based and sound engineering judgement is required to make decision for desired solution. Design is developed in the conceptual phase using analytical software and at a later stage the design is evaluated using the same analytical software.

Design software is useful for physical modelling, building the plant & maintaining it. Required attribute level information is collected at different stages of design from various stake holders. Some design software has limited calculation abilities that helps making some calculation decisions to evaluate design. However, mostly the design software is used to count the design quantities, measure the design progress and interface with other software design tools. There is some proprietary design software such as for EHT, protection relay setting & configurations which are typically vendor specifics.

Commercially available spread sheets could also be converted into a tool for supporting design at various stages. Spreadsheet solution poses validation, and integrity challenge and if not taken care properly this could lead to unwarranted issues on design and design calculations.

There is often a large gap between analytics-driven insights and enterprise scalability. This is due to the massive volumes of data from multiple databases. In order to scale across an enterprise, new paradigms for data contextualization are necessary and will likely combine domain expertise with machine learning. You can scale advanced analytics across assets, ultimately yielding faster times to diagnostic, predictive, and monitoring insights.

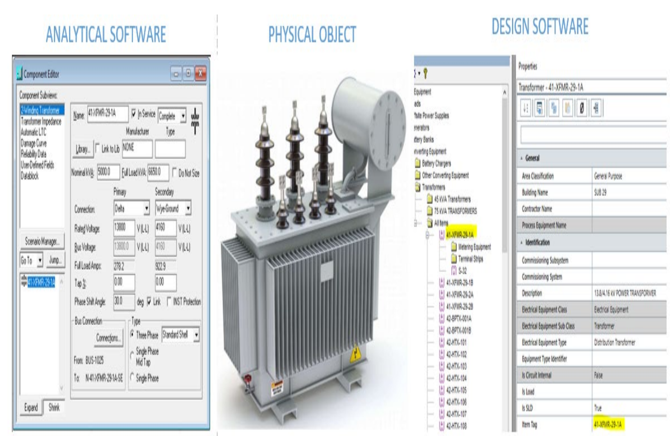

Fig. 2 Software Representation

Information may be transferred from analytical software to design software for the purpose of data continuation and later in the project, from design software to plant operation & maintenance software. This same data could be transferred to a management dashboard. This data transition needs validation prior to using it to manage critical information to suit specific purposes, however, uncontrolled transfer could lead to data clogging or negatively impact network efficiency.

IV. TOOL INTEGRATION

The commercially available design tools are not developed for one discipline, rather they are available for all other engineering disciplines. Each discipline specific module can perform the design task independently as well can be integrated to transfer relevant information to other tools tool. This collaboration feature is very useful as it reduces the manual effort and maintains the design data consistency across the different design tools.

The vendor specific tool integration for different disciplines is limited to specific vendor only. Open-source software design tools are not available in the market that can integrate to other discipline tools of another vendor. With more design tools available with API functionality this limitation may be overcome in the near future.

The integration of analytical software with design software adds another dimension to overall design efficiency where all the conceptual design developed in analytical software (with all tags) are transferred to design tool along with associations & references. This level of integration allows us to maintain design consistency and data integrity. It is important to note that this integration is typically not dynamic in nature. Change of information in one tool does not reflect in other tool or other data repository. An instance needs to be created to transfer the information from one tool to another tool. Instance-based data transfer helps maintain data maturity, validation and required scrutiny, before it is consumed by other tool, entity, and/or data consumer.

V. DIGITAL TWINS / PLANTS

A digital twin is a virtual model of a physical asset or process. When taken further, a digital plant is a virtual replica of an entire facility or process. Digital twins help enterprises to understand, predict and optimize the performance of their assets. A digital twin allows one to pro-actively identify risks, look into the future (predictive), and save time and costs, especially on maintenance activities.

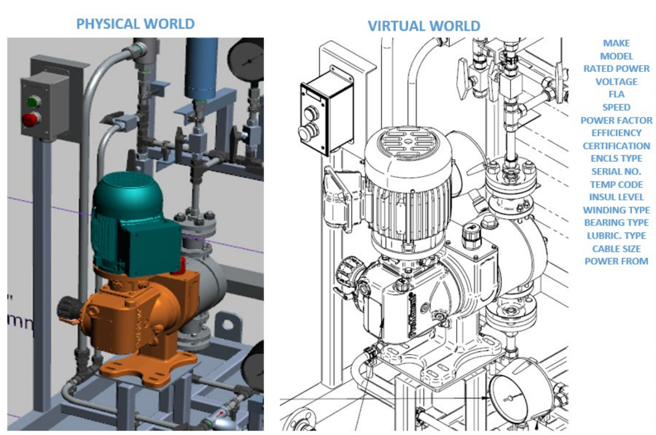

Fig. 3 Digital Twins

Digital twins can be further classified as

1. Component Twins are the digital representation of a single element of an entire system e.g. induction generator as part of a wind turbine
2. Asset Twins are two or more components that work together as a part of a more comprehensive system.
3. System Twins are typically comprised of groups of asset twins that work together at a system level. and
4. Process Twins which is the final level of digital twins.

Plant managers use process twins to understand and analyze how all the various units within the plant or process collaborate. With a process twin, one can model the impact of tweaking inputs, such as the rate of feeding in the raw materials, the process temperature etc. in order to determine how this would affect outputs without risking wasting resources on failed experiments. Fig. 3 above is an example of a component twin.

The value of digital twins in process manufacturing:

- Reduced downtime and costs
- More efficient use of resources
- Greater productivity
- Strategic planning
- Increased safety
- Improved innovation

Machine learning can help decode and interpret design data across disciplines and lifecycle stages. This would reduce the data conditioning time and speed up the time to value.

VI. VENDOR / SUB-CONTRACTOR DATA COLLECTION, CONDITIONING & UPLOADING

The design data that is useful for the plant construction, operation and maintenance is equally produced by vendors, sub-vendors, sub-contractors, and equipment manufacturers.

At the beginning of the project, the dataset required for the digital model shall be conveyed to all the sub-contractors, vendors and sub-vendors with a proper format and template to maintain consistency of received data. This consistency will also be helpful while uploading the data.

The data received from different sources may not be in a consistent format or same file type. The design data needs to be conditioned and massaged before uploading it for the next data consumer. This data conditioning is very important and should be done very carefully to maintain data integrity and continuation from one phase of the project to another phase of the project.

Various utilities can be used to upload the vendor, sub-vendor, sub-contractor data to the main design tool for completion of design that can be transferred for plant operation and maintenance. Without this important piece of information, the design data will not be complete and plant operation or maintenance personnel will not be able to utilize full scale digitization.

VII. REPORT MANAGEMENT

Generating the information to support the needs of the enterprise is a fundamental requirement of the database. The report management could be in formal documentation or could be on daily or weekly reports. The report could also possibly be put in the form of daily or weekly dashboard format. The reports for formal documentation and drawings are drawn from design tools or from analytical software with some modification to the out of the box reports. The report definitions can be changed based on the project requirement or organization need. The reports are also used for material management and procurement purposes other than technical analysis and design confirmation purposes.

The daily report format may be managed based on the requirement. On one of the large LNG projects, the defined data is pulled from various tool databases, flattened and then the data is formatted for various reports. This way of representation allows to join tag with other relevant information and not strictly confined to tool database classification. The management reports, progress reports, and completion reports are better derived this way.

VIII. EDGE COMPUTING

Industrial control has been around for many years. During this time, new technologies have emerged, been implemented, and led to increased yields and quality improvements. Original industrial manufacturing systems began with autonomous stations, independent islands of production, perhaps in the same facility, with serial flow between isolated workstations. A good example of this was the early automotive assembly lines. Innovation from this initial primitive starting point has been a gradual move toward centralizing the control of the overall process. This has been the trend for many years; the centralization and integration of independent control systems. Equipment such as programmable logic controllers (PLCs) and distributed control systems (DCS) have been the means to bring things together.

As devices have become more intelligent, increasingly more remote control and information are available to be taken back to central control. One of the challenges which impeded the integration process has been the independent development of intelligent devices and networks without the necessary design standards being in place to coordinate the efforts of individual suppliers. This has led to disparate systems which have required SCADA systems and other intervention and measures in an attempt to combine them. Examples of disparate systems are IT, power distribution and process control. Combining these islands has been the primary focus shifting away from islands of automation, where these systems were kept separate and even designed and managed by distinct groups. As a result, these subsystems have been disparate and not amiable to an integrated approach which would merge operational technology with information technology on the plant floor. Recent efforts and successes to merge these systems has been the driving force for IIoT, Industry 4.0 and China 2025. Fig. 4 is showing an overview of a future typical facility being operated from SaaS in the Cloud and from the Edge.

Bringing IT into the operations world means that new software and associated approaches are now available as well. Linux based systems, typically used in IT applications, have not been all that prevalent on the plant floor. Applications utilizing Linux based approaches are being combined with OT industrial control technologies in order to improve plant floor performance. Manufacturing is implementing IIoT based systems that integrate plant floor equipment with

Fig. 4 System overview

Cloud based services. Centralized data facilitates an enterprise view of production, equipment health and manufacturing. Plant floor workers are now connected operators that have a clear view of the status of their equipment as well as data on upstream and downstream processes enabling them to make informed decisions.

While all this has been going on, another technology has been emerging in part due to the discussion above. Edge computing. Everything old is new again. For those familiar with programmable logic controllers, distributed control is nothing new. People familiar with OT who have experience with edge-based computing systems, this development is nothing new.

Edge devices facilitate the combination of real time control with IT based applications that support valuable analytics for the operator as well as for the enterprise. This approach provides real time control and monitoring of the process and provides the local capability to perform computations needed to analyze the plant floor data locally speeding up scan times. This satisfies the needs of both the OT and IT worlds. By having the capabilities at the application location, this eliminates the need to transfer data to the central controller and the required processing capability. Instead, machine learning algorithms, for example, are performed locally and will not slow down the entire process while doing so.

Edge devices bring other benefits. Items such as multiple control languages, ladder logic, interfacing to multiple industrial network protocols when and where needed, Linux based applications involving computations needed for analytics, etc. They also support IIoT Protocols such as MQTT and OPCUA to interface with cloud-based applications. As can be seen, edge computing addresses numerous challenges particularly in the areas of managing, collecting and computational with respect to the streams of data being produced by the IIoT system. It is important and recommended to have an edge management plan if the use of distributed edge surfaces increases as expected in order to streamline edge controller use and avoid security risks.

IX. CYBERSECURITY CONSIDERATIONS

The rapid deployment of connected and intelligent OT devices means that manufacturers have never been more vulnerable to cyber-attacks and the associated unplanned downtime which in turn means greater financial and operating risks including risk or loss of life. In other words, facilities are at greater risk of cyber attacks as more OT and IT systems are converged. It has been projected that $5 trillion in losses due to security breaches will occur over the next 5 years. What can be done to avoid this? Database software, along with asset management and defense in depth techniques, are used to ensure system integrity [4], [5], [6], [7]. Strong governance particularly when integrating with IT systems (like Single Sign On) helps reduce the risk of cyberattack. Zero Trust as a strategic approach to security has been a recent introduction as well. Zero Trust is a cybersecurity philosophy that secures an organization by eliminating any inherent trust to individuals or groups and require continuous verification of every stage of a digital transmission or interaction. Further to this, limiting the exchange of data to information that is valuable to the enterprise. There is a need to balance access to information with cybersecurity. The data should be of value and not simply manipulated because it is possible to do so since transferring and manipulating a larger and more comprehensive database does increase the risk of cyberattack due to the exposure of this data across the enterprise. The authors would suggest that the database be designed to accommodate all conceivably possible future transactions but limited to the exchanges that are identified as necessary to support the enterprise. Transferring the data involves utilizing connectors and extractors. Each transmission provides an opportunity for an attack so reducing and limiting these is a factor.

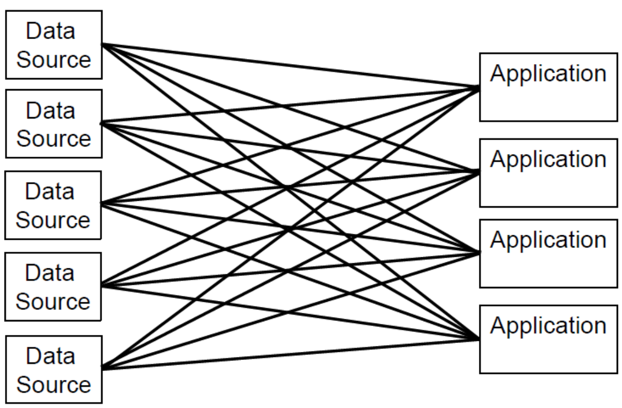

Fig. 5 Lack of common data management strategy (Sources X Destinations)

To illustrate this point, let us consider the way connectors and extractors are utilized to transfer data. Fig. 5 is illustrating the number of possible connectors if a common management strategy in the middle of the database is not utilized. Without a common data management strategy in the middle, you have (Sources X Destinations) of possible connectors.

On the other hand, with a common data management strategy, see Fig. 6, the number of possible connectors is reduced to (Sources + Destinations) of possible connectors. It is evident that as an enterprise scales up, the major difference that this approach will have in reducing the overall database complexity and simplifying the transactions.

The digital relays and other components that can directly communicate to network or data directly shall be equipped with enhanced cyber security capabilities. Current offerings from most component manufacturers have these enhanced capabilities.

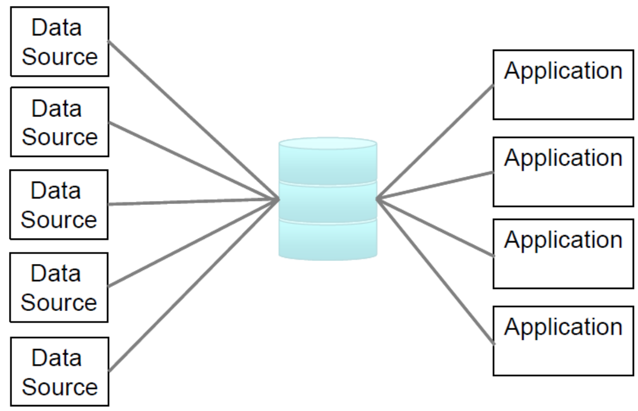

Fig. 6 Common data management strategy (Sources + Destinations)

X. ASSET TRACKING & MANAGEMENT / LEAN MAINTENANCE

One of the tasks for which a database system can be utilized and is well suited for is to address asset tracking and management. The further benefits, in addition to the classic benefits of this activity, relate to security and maintenance. Having an accurate accounting of the equipment on the system, managing change, etc. protects against both malicious attacks and accidental incidents on the system.

Lean maintenance involves the reduction and elimination of waste at every stage of the maintenance program allowing the enterprise to go further faster, while spending less. There are 3 types of waste in the maintenance process: environmental, financial, and wasted effort.

Environmental waste occurs when raw materials are used or disposed of inefficiently because of ineffective maintenance activities. Examples include scrap and rework due to equipment being poorly calibrated, fuel waste – excessive trips to site(s) and overstock / outdated maintenance parts due to outdated inventory list and schedule. Techniques which would be beneficial and supported by an accurate database include:

- Frequent inventory cycle counts / reduced inventory purchasing to minimize stock.
- Grouping scheduled maintenance to reduce travel.
- Verification of product specifications after repairs or replacements before production, to reduce scrap or rework.

Financial waste relates to extra costs due to inefficient maintenance practices and associated lost production due to avoidable downtime. Examples include:

- Higher costs than necessary because PM performed too frequently.
- Defective product from an asset that was assembled or rebuilt incorrectly.
- Delayed maintenance waiting for a part to complete repairs.

Some strategies for reducing financial waste include:

- Reduce or eliminate PM when possible.
- Perform maintenance while the asset is running.
- Add failure reporting, analysis, and corrective action system to database for critical equipment.
- Kit repair packages for equipment

Wasted labor includes administrative work and unnecessary tasks that take maintenance personnel away from more productive tasks. When this situation becomes chronic, poor morale and staff turnover increase, leading to additional waste and lost organizational knowledge. For this reason, data and reports should be categorized into critical and less important categories.

Using a computerized database system allows for the reduction and elimination of repetitive work such as reports, scheduling work which must be completed and trending failures which might occur. The above waste can be mitigated to a large extent by taking a proactive approach that hinges on data rather than a reactive one.

Recent supply chain issues illustrate why it is critical to understand spare part schedules, inventories, and lead times to ensure that there is sufficient material on hand to address possible contingencies and to avoid prolonged shutdowns.

XI. RECOMMENDATIONS

The authors would like to offer the following advice with respect to selecting and using data collection and analytic tools based on our experience.

- If the project is brown field, begin by examining the operation from where to start collecting data, the analysis of this data through to the resulting decision-making strategies.
- For a new project, particularly if the process is new, the team may not have sufficient operating experience to draw from and, therefore, should err on the safe side from the design perspective.
- Include all stakeholders and process experts as well as data specialists whenever possible in the planning and assessment opportunities as they arise during the timeline of the project. Operators, in-house data management personnel and other workers should be included to get their point of view.
- Focus on improving the process and the KPIs that would be required to do so.
- Perform a criticality analysis to prioritize which equipment and what data to draw information from.
- Spend more time at the beginning of the project planning and assessing to ensure that the objectives and goals are understood and addressed since recovering later in the project is far more expensive and will cause more delay.
- Ensure that the technology you intend to use can scale across the plant and enterprise.
- In fact, design the technology to have a capacity well in excess of any foreseeable requirement based on the present expectations.
- Utilize the system to gather the data that is actually required but make provision for future expansions that may arise due to new technology and insights.
- Have a common data management strategy which will minimize the number of connectors and extractors.
- Use a major provider; one that will have a high probability to be around to support the facility for the projected life span.

XII. CONCLUSION

As can be seen from our discussion, there are numerous items which must be considered when implementing a digital strategy for a new facility. To realize key goals such as optimized production, network security and advanced reporting over the 40+ year life for a facility, this must all be considered in design. With the pace of change currently being seen, this is a tremendous challenge. The authors believe that the best approach to realize the greatest performance and system longevity is to utilize a database approach which covers as many of the items discussed in this paper as possible based on a sustainable universal platform with long term flexibility.

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XIV. VITAE

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