MITLGO

LEADERS FOR GLOBAL OPERATIONS

LGO Class of 2023
Knowledge Review Use Case Summaries

LEADERS FOR GLOBAL OPERATIONS

LGO Class of 2023
Knowledge Review Use Case Summaries

Onyinyechi Chiemela (Ukay) Ukaire	Predicting and Preventing Unsafe Events	Amgen	108
Shelby Unger	Analysis of Respiratory Time Series Data for Breathing Discomfort Detection	ResMed	110
Alura Vincent	Designing a scalable data science solution to improve forecasting and allocation of orthopedic sets	Johnson & Johnson	112
Joshua Weisberg	Enhancing Manufacturing Performance to Plan with Predictive Analytics	Nissan	114

Nuclear Microreactors as a Clean Energy Source for Data Centers and Mining Sites

CATERPILLAR®

BUSINESS PROBLEM

This thesis explores the possibility of using nuclear microreactors as a clean, reliable, and safe energy source for mining and data center industries. These industries currently rely on third-party energy generation companies and need alternative technologies to reduce greenhouse gas emissions. The thesis has three objectives: to understand if nuclear microreactors can meet the technical requirements for powering mine sites and data centers, to evaluate the commercial feasibility of this technology in an industry setting, and to describe the sustainability impact of using nuclear microreactors instead of fossil-fueled power.

APPROACH

To solve this question, we look at the technical capability of the technology of providing power in the quantity and quality needed. Secondly, we compare the nuclear microreactor technology with other energy generation sources to understand the commercial competitiveness. Thirdly, we explore the carbon abatement potential of this technology. We leverage simulation tools to achieve these objectives

DATA SOURCES

Vendor and customer interviews, market intelligence from Caterpillar and MIT Libraries, disguised and aggregated customer data, load profile information simulation, LCOE and LACE internal and external estimates, ESG reports, industry research.

Data Types and Format

Spreadsheets, simulation software, research papers, market intelligence reports, videoconferences

1. **Assess technical feasibility**
   - Understand vendor and customer needs
   - Characterize technology and applications
2. **Value commercial potential**
   - Calculate expected and compared cost of energy
   - Define market value for relevant industries
3. **Estimate ESG impact**
   - Calculate carbon abatement potential
   - Understand embedded carbon across value chain

Author: Santiago Andrade Aparicio

IMPACT

With the increased pressures by customers to deliver more sustainable power solutions, Caterpillar remains focused on evaluating potential technologies like the emerging nuclear products and the potential impact on key market segments they support. The technical and commercial feasibility analysis will enable Caterpillar to act on upcoming investment and research decisions which enable a portfolio of products and services that support their customer's sustainability goals, as well as their own. The project will ultimately inform executives on whether they should continue to research the nuclear microreactor as a potential avenue for clean energy generation to support mining and data center applications for 2030 and beyond

DRIVERS	Customers in the Mining and Data Center segments have set aggressive goals related to the reduction of GHG emissions by 2030. In support of these goals Caterpillar is involved in several electrification initiatives which will depend on reliable, clean electricity.
BARRIERS	Information around Nuclear Microreactor technology is scarce given its current stage of Research and Development. For this reason, informations related to cost and operation was mostly compiled from informed assumptions provided by MIT and non-MIT experts
ENABLERS	Caterpillar and MIT enabled access to the HomerPro software platform which has heavily used to perform all the simulations needed to answer the question defined in the problem statement.
ACTIONS	Given that this was a more research oriented project, the solution that came out as a result was that of communication and information access. The results and the potential impact of this technology were communicated across the company in a variety of ways including videocalls, in-person meetings and documentation. The project gave brith to a follow-up internship which will try to find a suitable operational and investment path for Caterpillar
INNOVATION	There were two main innovative aspects of this project. The use of the commercially available energy grid optimizing software for a purpose it was not originally created. Find a way to incorporate a nuclear microreactor into a platform that was not designed for that required and innovative approach. Secondly, the technology itself is innovative as it is still under R&D and its impact can not yet be fully understood.
IMPROVEMENT	Caterpillar has now access to a database of results that spans two industries and several different types of scenarios. These results, including the sensitivity analysis, will enable Caterpillar to make informed decisions on the strategy to decarbonize.
BEST PRACTICES	Two practices were well demonstrated in this project. Organization-wide communication, where we brought on board the project members across different divisions and teams to ensure full support and feedback was accessible. Moreover, project scoping was done early in the process and with a lot of detail to ensure that the remaining time of the project could be used in generating accurate results to answer the agreed upon problem statement
OTHER APPLICATIONS	The nuclear microreactor, as well as the methodology developed to understand its technical and commercial feasibility, can be used to explore the viability of this technology in other industries or similarly with other technologies.

Operations | Retail | Transportation optimization | Supervised Learning

Transit Time Prediction for E-Commerce Fulfillment Optimization and Carbon Emissions Reduction

BUSINESS PROBLEM

Consumers are purchasing an increasing amount of goods through digital channels as compared to brick and mortar and expect fast, reliable delivery. At the same time, society is facing the urgent challenge of climate change mitigation. A global sportswear retailer is investing in improving digital consumer experience while meeting its aggressive 2030 carbon reduction goals. This work focuses on improving critical operations decisions such as which distribution center and shipping speed to use in digital order fulfillment as a method to enhance consumer experience and reduce carbon emissions.

APPROACH

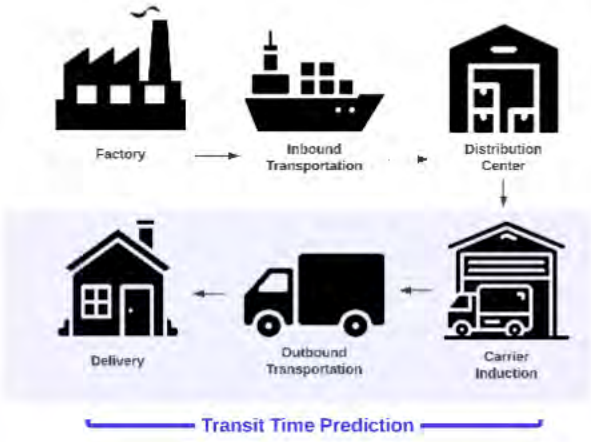
This work focuses on enhancing the accuracy of a highly influential input in the distribution center, shipping speed selection algorithm as a method to improve the quality of those important fulfillment decisions. Specifically, this work uses machine learning to predict transit time, or the number of days between third-party carrier network induction and parcel delivery.

DATA SOURCES

Two key datasets were identified and and procured: an internal North American digital order fulfillment dataset which provides attributes related to a parcel's journey through the supply chain (distribution center onward) and a carrier transit time estimate dataset that is provided by carriers to the organization as a method to communicate service levels.

Data Types and Format

The fulfillment dataset exists in a SQL-like data warehouse and includes categorical and numeric variables. The transit time dataset exists in a set of CSV files and includes numeric variables.



Author: Kathryn Angevine

IMPACT

The transit time prediction model developed in this work is associated with an accuracy of 67%. This is an improvement over current state estimates which are associated with an accuracy of 45%. A counterfactual analysis is conducted to assess the impact of improved transit time estimates on key digital fulfillment performance indicators. On a one month sample, the model enables improved fulfillment decisions. When compared to decisions made using the current state transit time estimates, the model enables fulfillment decisions that are associated with a 4.5% reduction in lead time, a 3% reduction in CO2 emissions and a 1.5% reduction in cost. This demonstrates how the transit time prediction model supports an enhanced digital consumer experience and the achievement of carbon reduction goals.

DRIVERS

Consumers are purchasing an increasing amount of goods online and as a result retailers are competing on and investing in their digital offerings. Additionally, society is becoming increasingly aware of the negative outcomes associated with climate change and businesses are now committing to carbon emissions reduction goals.

BARRIERS

Identifying source of truth data sets, processing data quality issues, and accessing adequate computational resources

ENABLERS

Access to expert-level mentors, strong team collaboration, high organization data fluency, and general data-driven company culture

ACTIONS

Interviewed 30+ stakeholders to understand problem space, formulated project scope, identified and procured necessary data, conducted exploratory data analysis, iterated and experimented with various model types and attributes, tested model on downstream systems, and conducted conversations with software engineering to discuss model productionization

INNOVATION

The approach consisted of many experimental iterations to determine favorable model characteristics. Experiments addressed model type (XGBoost, CatBoost, Random Forest, CART, etc) data set size and time period, winsorization, sampling, feature engineering, feature selection, etc.

IMPROVEMENT

Transit time estimate accuracy is now 67% instead of 45%. On a one month sample, the model enables fulfillment decisions that are associated with a 4.5% reduction in lead time, a 3% reduction in CO2 emissions and a 1.5% reduction in cost.

BEST PRACTICES

Start small and simple, iterate and add complexity over time as needed, identify a small but key group of stakeholders and keep them involved in the process, use visualizations and storytelling to gain buy in, focus on realizing incremental improvement as soon as you can, and don't get caught in an endless cycle of model improvement

OTHER APPLICATIONS

This model can be applied to other businesses that sell physical goods online and are trying to reduce carbon emissions and improve consumer experience through enhanced fulfillment processes.

Operations | Retail | Warehousing automation / flow optimization | Discrete / Continuous

Visual Sort Marker Digitization in Sort Centers Operations

Amazon

BUSINESS PROBLEM

A previous initiative aiming at the reduction of the shipping label size, the Small Shipping Label (SSL) has a potential entitlement of >$188. SSL implementation requires the removal of a physical VSM from the package label. Currently a critical manual processes in Middle-Mile operations (Sort Slide) rely on physical VSMs to inform sortation decision making at the package level. Manual sort centers will require technological advancements to remove the existing physical label dependencies. Amazon is working towards the removal of physical VSMs while mitigating any risks to Throughput Per Hour(TPH).

APPROACH

A current state assessment and time study took place to understand the on-going set of circumstances of the Sort Slide Diverter process and its capabilities, as well as gather baseline cycle times. These analysis were consequently used to quantify and determine the impact and viability of the technologies deployed to enable the removal of the current physical VSM.

DATA SOURCES

Even though Amazon has an extensive number of databases available, Sort Slide specific data is very limited given the manual nature of the process. This information will be gathered manually, either by the researcher or by the respective location's Area Managers. Sort Center network existing data regarding labor hours, volumes and rates will be used for network wide analysis.

Data Types and Format

Most of the data is contained in SQL DBs. It can be accessed online or via Excel spreadsheets.

Author: Nayeli Arellano Martinez

IMPACT

Manual dependencies limit inflight shipment replanning to handle events such as missorts, unpredictable weather conditions, truck break downs, etc. Elimination of reliance on physical VSMs will provide the ability to load balance volume in a short timeframe among nearby sort centers. It will also provide the ability to ship items in packages smaller than the current 4x6 shipping label. Smaller labels facilitate the use of smaller shipping boxes, which ultimately reduces the overall amount of packaging materials required. This reduction in packaging materials, in turn, contributes to a decrease in the carbon footprint associated with transportation. Smaller boxes translate as optimized truck space, since more packages can be shipped in a single trip. As a result, the number of trucks or planes required for delivery is reduced, reducing associated fuel consumption and emissions. Thus, bringing the company closer to meeting the Climate Pledge sustainability goals.

DRIVERS

The Small Shipping Label (SSL) program presents an incredible effort to improve Amazon's carbon and material footprint (an estimated 500K MT of carbon footprint reduction annually). It also allows for uo-to-date transportation plan information through the entire shipping process, eliminating the need for associates to sideline, re-plan and re-label packages when re-routing is required.

BARRIERS

At the beginning of this project there was no data available regarding capacity or quality of the Sort Slide Diverter process. A baseline needed to be built from scratch to be able to assess the impact of VSM removal in the Sort Center Network.

ENABLERS

Amazonians consistently exhibit a willingness to collaborate in order to enhance processes and resolve challenges. In fact, they actively promote innovation and the exploration of novel ideas and concepts. This project involved multiple teams, and each relevant stakeholder displayed enthusiasm towards comprehending its scope and sharing their expertise.

ACTIONS

A "scrappy" in-person test was developed to assess the associate's reaction to the proposed solution. The Operations' teams from different sites were involved and participated in the assembly of the station to be tested. The test results were analyzed vs the previously created baseline and recommendations were given regarding the necessary data for the next steps in towards project's implementation.

INNOVATION

Companies and their supply chains continuously seek technological advancements to achieve sustainability and resilience in their supply chains. This project looks into the operational challenges of implementing sustainable practices by assessing the trade-offs between sustainability and productivity. This trade-offs are often intangible and rely on qualitative data for measurement.

IMPROVEMENT

The main quantifiable improvement is capturing the network-wide impact on the Sort Slide Diverter performance from each proposed solution. The analysis suggests that accepting a modestly degraded process rate might be a viable trade-off if it helps an organization achieve its sustainability goals and ensures the long-term viability of its financial growth.

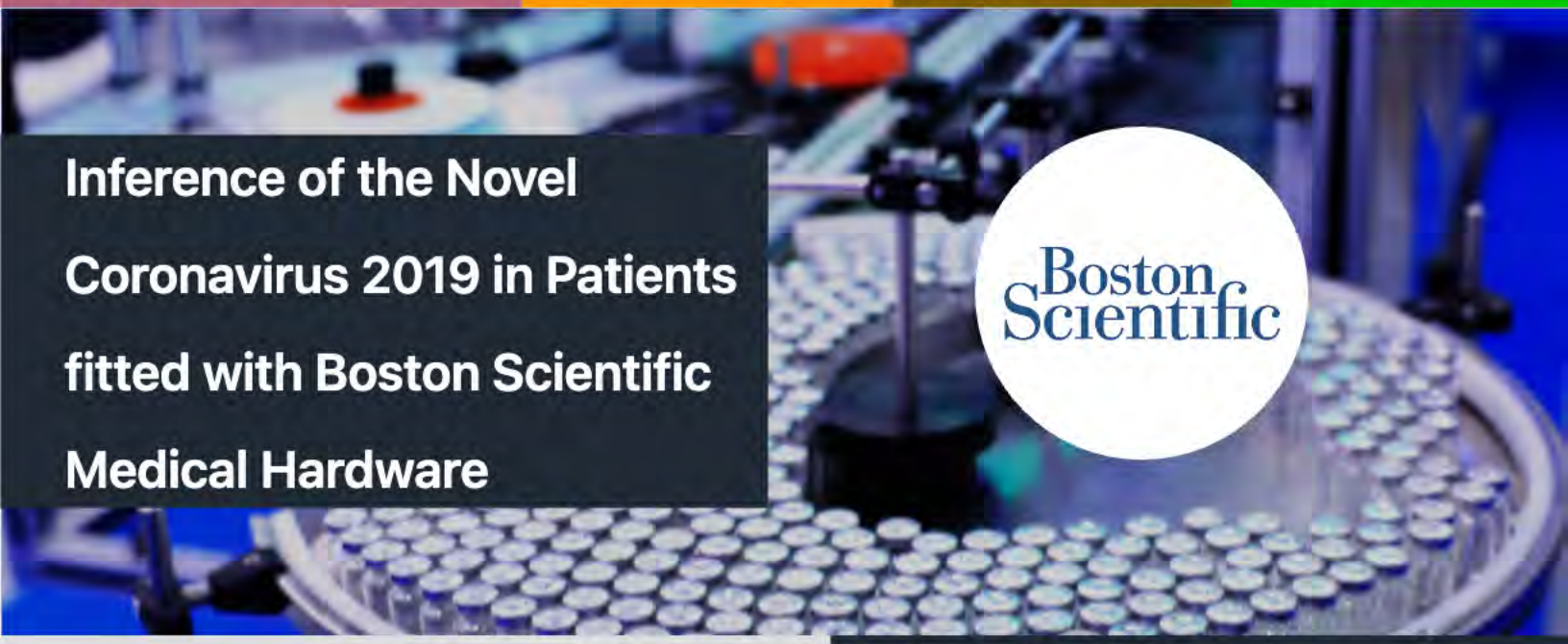
BEST PRACTICES

The process followed for this project (assessing current state and creating a process baseline, analyzing each proposed solution vs the baseline, performing in-person tests when possible, and accounting for each solution associated costs) can be easily replicated and can potentially help other teams with similar solutions' analysis and implementations in their respective areas.

OTHER APPLICATIONS

This approach can be applied in any process improvement initiative, specially when assessing retrofitting vs new technology implementation, and their respective trade-offs between sustainability and performance.

Product design / development / engineering | Healthcare / Pharmaceuticals | Product design and testing | Semi-Supervised Learning



Inference of the Novel Coronavirus 2019 in Patients fitted with Boston Scientific Medical Hardware

BUSINESS PROBLEM

Heart failure Patients using Boston Scientific's rhythm management (RM) devices such as pacemakers and CRT-Ds tend to be in the high-risk category for COVID patients and in fact the COVID mortality for these patients is 3.58x higher than for other patients. In 12.3% of mild cases these patients will escalate to hospitalization more than 1 week after diagnosis. So, how might we build a product that aligns with the business strategy and direction by helping to anticipate worsening COVID-19 symptoms in real time in patients and therefore provide them with better healthcare solutions by intervening in a timely manner.

APPROACH

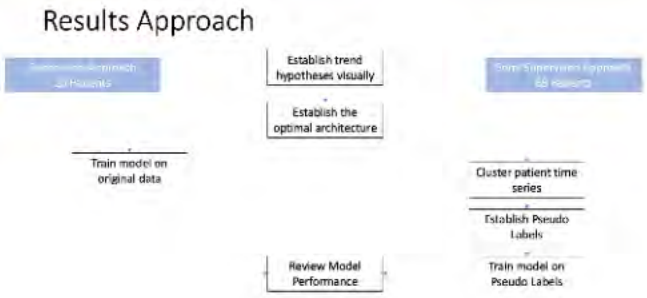
Leverage retrospective sensor data from patient's rhythm management devices and reported symptom data establish if there were any data points that would indicate worsening COVID symptoms at an individual, regional, or population level. From these data points I aim to produce an algorithm that can anticipate COVID just from patient cardiac data.

DATA SOURCES

The LATITUDE database stores data from 500,000 patients for every type of RM device that Boston Scientific supports. For my thesis though I will have access to only patients who have consented to the study via a questionnaire. This means I have access to data from 300+ patients. I have access to 162 columns of demographic data from the questionnaire and 50 columns of time series data from LATITUDE

Data Types and Format

LATITUDE Data: Cardiac time series data at the daily level. This dataset shows these trends before and after COVID onset.
Questionnaire Data: Demographic data from consenting patients.



Author: Daniel Ayane

IMPACT

Boston Scientific is facing competitive pressures to reinvent its rhythm management (RM) division. Firstly, the division is facing a shrinking market. The availability of RM devices is increasing with the rise of wearables and other sensors from non-medical device companies. The RM market is becoming commoditized, so BSCI needs to differentiate its devices to provide a competitive edge. So, adding additional services to their already existing product line provides extra incentive to buy BSCI hardware while also increasing its usefulness lifespan. Secondly patients want more utility from their devices. In some cases, BSCI's patients want feedback from their devices that are essential to their lives. Providing services that allow their patients to derive utility beyond the single therapy usecase that the device was designed for increases customer satisfaction without increasing the cost of the device. Finally, there is a moral incentive for Boston Scientific to provide insights into data that it already has. As a medical device manufacturing company, they have a duty to patients and physicians to help improve patient care. This duty is beyond financial, so by finding insights into data assets that only BSCI has access to and then publishing this information it furthers the field and provides a public good through education.

DRIVERS

The industry faced large losses due to the COVID-19 pandemic. So there was an increased focus on remote patient monitoring and remote case support from Boston Scientific's customers. Moreover, there was an increase in customer demand for handling sudden cardiac arrests, improving device comfort, and providing additional innovation from patient devices.

BARRIERS

This thesis's major limitation was the data's size and variety. The dataset used was largely unlabelled, with 49/69 patients not reporting a PCR test so their COVID-19 status is largely unknown. Additionally, of those who have reported their COVID-19 status, their patient demographics are largely homogenous meaning a lack a patient diversity and limited generalizability of the final model.

ENABLERS

Aligned incentives at the company allowed quick approvals and open data sharing between teams. I was able to reach out to anyone at the company for knowledge transfers and advice because everyone was aligned with the innovation culture at Boston Scientific and specifically the Digital Health Studio team.

ACTIONS

Create a time series slice feature set that contains the most relevant COVID-19 distinguishing features then cluster these time windows using constrained K means clustering. Identify the cluster that represents COVID-19 the best. Utilize that cluster to pseudo-label the time windows. Train two models, one using known labels and another using pseudo labels. Evaluate the model performance of each model using clinically relevant metrics.

INNOVATION

The semi-supervised portion of the project is a novel approach to maximizes the utility of a largely unlabelled dataset. Boston Scientific has not combined constrained K means clustering and supervised learning to deliver improved patient care and this process is novel and potentially extensible to other datasets in the company.

IMPROVEMENT

The solution provides the company with 2 proof of concept algorithms that demonstrate the power of data to help improve patient care. With a limited dataset and low cost, the models are shown to give patients advance warning of a worsening COVID-19 condition and bolster the case for further research into the predictive analytics field.

BEST PRACTICES

To replicate and improve on this solution it is best to ensure that your training dataset is large, diverse and clean. This can be achieved by pairing LATITUDE data with data from trials that establish the disease onset classification labels in a clinical manner for example through a PCR test. Additionally a larger patient population will help ensure the generalizability of a future solution.

OTHER APPLICATIONS

The process used in this thesis could be used to help build algorithms that predict worsening disease onset conditions for other diseases such as COPD, Arrthymias and Heart Failure.

Operations | Transportation and logistics | Predictive forecasting | Ensemble-based (bagging, boosting, stacking)

Modeling Passenger EV Charging Demand with Machine Learning Using Telematics Data and Temperature

nationalgrid

BUSINESS PROBLEM

The purpose of this research was to analyze passenger EV charging data from National Grid's Massachusetts EV Off-Peak Charging Program, the largest service-territory-specific EV charging data set the Company possessed , and determine whether scalable supervised machine learning models could be built to predict EV charging demand, and further determine the lowest geographic granularity of such models. This research and the resultant models aim to support more deliberate distribution infrastructure planning, inform electricity rate design, and improve managed EV charging programs to mitigate the impact of EV proliferation on peak energy demand.

APPROACH

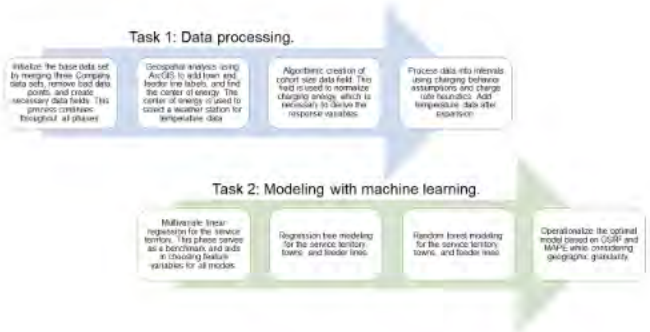
Modeling employed supervised machine learning methods with random forests being deemed optimal. This research was novel in its charge rate estimation methodology, normalization of charging energy to a per-vehicle basis, accounting for charging energy demand flowing into and out of the system being studied, and the addition of ambient air temperature as a feature variable.

DATA SOURCES

1.) Data from National Grid's Massachusetts EV Off-Peak Charging Program. 2.) Temperature data from Independent System Operator - New England (ISO-NE). 3.) Feeder line shape file from National Grid. 4.) Energy utility and town bound shape file from MassGIS.

Data Types and Format

All data was structured and processed locally as .csv files.



Author: Adam Barber

IMPACT

Understanding when customers charge their EVs and how much energy they consume better enables the Company and other electric utilities to provide more reliable and affordable energy to all customers while aiding the transition to clean transportation. Ultimately, this research successfully created and operationalized an acceptably-accurate random forest model at the service territory level and illuminated the challenges associated with utilizing telematics data for demand modeling. The operationalized model was packaged into a save file which is loaded by an executable demonstration program that predicts passenger EV charging demand based on a temperature data file designated by the user. The program requests the number of EVs to scale its prediction and outputs the peak energy demand magnitude and time of year, along with graph that shows predicted demand by hour of year. The program can be used to generate lagging or forecasting demand predictions depending on the user's needs.

DRIVERS

Interviews with several stakeholders, ranging from managed EV charging customer program leads to data scientists, provided a detailed cross-functional view of how data are generated and analyzed within the Company. With a fresh perspective on the problem and guidance from several subject matter experts, an innovative approach and solution were generated.

BARRIERS

The telematics-based nature of the data and the lack of separation of charging energies into time intervals made this research very challenging. The vast majority of time was spent on data manipulation and preparing variables for modeling. However, after the data were organized and the preferred machine learning method, random forests, was identified, the modeling process went very smoothly.

ENABLERS

Employees in the Company were highly communicative and easy to approach. Answers to critical questions and mentorship were easily found throughout the internship by simply sending a meeting invitation and preparatory email. Feedback on research was timely and highly detailed.

ACTIONS

The operationalized model was packaged into a save file which is loaded by an executable demonstration program that predicts passenger EV charging demand based on a temperature data file designated by the user. Additionally, the data manipulation and modeling processes were carefully recorded to support future work.

INNOVATION

1.) Utilizes heuristics to estimate charge rates and uses the estimates to divide the data into equal time intervals. 2.) Charging energy is normalized on a per-vehicle basis in order to create scalable models. 3.) The models generated attempted to account for the influx of vehicles into the system and the efflux of vehicles out of the system. 4.) Ambient air temperature was added as a feature variable to increase model accuracy.

IMPROVEMENT

The Company now has an additional modeling tool based on highly specific and relevant data. More importantly, a process and set of recommendations were codified to enable better model design in the future.

BEST PRACTICES

1.) Request interval data that displays normalized energy consumption. 2.) Allow data to become more dense, perhaps over course of one additional year. 3.) Experiment with unsupervised learning methods. 4.) Temperature should be sustained as a feature in future predictive modeling for EVs. 5.) Incorporate more environmental features, such as precipitation, or temporal features that are easily derivable from a date, such as day of year or month.

OTHER APPLICATIONS

Given the niche application of the solution, it is not likely that the exact approach would work for a dissimilar problem. However, other electric utilities could utilize this research to create their own models from telematics data.

Production engineering | Aerospace and defense | Improved process performance | Systems-Theoretic Accident Model and Processes

Application of System-Theoretic Analysis to Work Movement in Production Systems

BUSINESS PROBLEM

In the aerospace industry, long product lifecycles, life extension programs, and highly specialized manufacturing capabilities combine to produce a challenge for OEMs in providing aftermarket support for fielded products. These factors drive the need for a work movement capability, where production of a product is physically relocated from one facility to another. The dynamics of work movement efforts are especially challenging when external suppliers are involved in support of long-lived defense products.

APPROACH

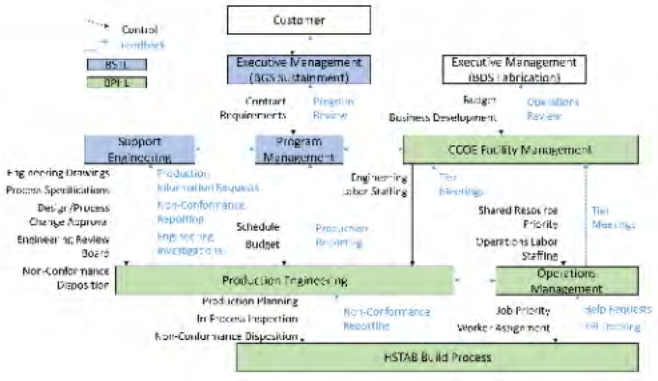
The principal investigation is a CAST (Causal Analysis based on Systems Theory) analysis of the fabrication and assembly of composite aircraft flight control surfaces at Boeing's Ridley Park, PA site, based on internship experience working with the operations and the engineering support teams. Additional background information was obtained through interviews, site visits and document review.

DATA SOURCES

The data gathered for this thesis can be grouped into three categories: interviews, documents, and observation. Due to the structure of the CAST analysis performed as the core of this research, the data-gathering process was necessarily iterative, with new information leading to questions, which then guided the search for further information.

Data Types and Format

26 interviews were conducted with a total of 23 individuals, ranging from 30 to 90 minutes. Documents included technical documents, correspondence, and executive briefing materials.



Author: John Barstow

IMPACT

The long lifecycle of many aerospace products means that aircraft with decades-old design still require support in the form of spare parts, leaving the manufacturer without a viable alternative to absorbing work if a supplier ceases operations. The recommendations generated by the CAST Analysis can be used to inform future decisions on work transfers, and provide a framework for establishing a production control structure when a transfer is required. Unlike more traditional analyses, CAST focuses on the control structure surrounding a production system, i.e. the structural, social, and communication relationships between stakeholders such as mechanics, managers, engineers, and other support personnel. Due to this emphasis on systemic causes of production failures, the recommendations are principally organizational in nature, and provide a effective countermeasure to the cost and schedule overruns and hidden factory effects that have been observed in past work transfers, despite previous efforts to mitigate these effects.

DRIVERS

The recommendations generated by the CAST analysis are strongly constrained by the business need to provide aftermarket support for fielded aircraft. Coupled with the complexity of defense products and a low production volume, the best solution available is to "do it right the first time" and thus avoid the cost and schedule risks that arise from shortcuts and mistaken assumptions.

BARRIERS

Geographic distribution, business unit relationships, and cultural differences all impacted the project significantly. Recommendations addressing these factors were developed in the analysis, but they remain a challenge for a large organization with a distributed international footprint.

ENABLERS

The close integration of Boeing and the LGO program was a great asset to the project. The availability of LGO alumni was very helpful in sourcing several interviews that made a significant impact on the project and thesis.

ACTIONS

The recommendations generated by the CAST analysis were briefed to leaders within Boeing. Due to the details of the program being analyzed and the nature of the recommendations, their implementation is a long-run prospect that will take time to yield results.

INNOVATION

The least intuitive aspect of the results is that OEMs should not expect or even attempt to exert complete control over supplier production processes. Instead, supplier relationships should be managed to maximize visibility, but in the event a work movement is required the OEM must carefully assess and test any assumptions made about supplier processes that were not fully visible.

IMPROVEMENT

The recommendations suggested by this project provide a framework for structuring an organization responsible for production restart after a work movement. If they are implemented, future work movement efforts may be able to avoid the creeping cost and schedule impacts that result from the mistaken assumptions uncovered in this project.

BEST PRACTICES

The CAST process that generated the recommendations is dependent on a detailed understanding of the system and the entities that operate within it. Any attempt to implement these recommendations as a solution must take into account the specific attributes of the product, process and organization(s) that are involved.

OTHER APPLICATIONS

The recommendations generated by this analysis were developed in the context of work movement and defense aerospace support programs, but the broader conclusions about configuration control and process model divergence have application in any production system. Designers and operators of such systems must be incentivized to share information whenever possible in order to avoid the worst effects observed during this project.

R&D | Healthcare / Pharmaceuticals | Product design and testing | Regression analysis

AI in the Cath Lab: Implications of Clinical AI-Enabled Assistance for Coronary Procedures

Boston Scientific

BUSINESS PROBLEM

Boston Scientific recently developed an AI-based clinical decision support system designed to assist physicians perform cardiac procedures such as the sizing of arterial stents. These procedures involve Boston Scientific's imaging catheter with intravascular ultrasound (IVUS), technology which visualizes the inside of patient vessels and improves patient outcomes. The AI model, which measures relevant areas of IVUS images, is theorized to reduce task time and generate higher usage of IVUS. However, there is no quantitative data demonstrating these effects, nor any software infrastructure for continuous monitoring and improvement of the model.

APPROACH

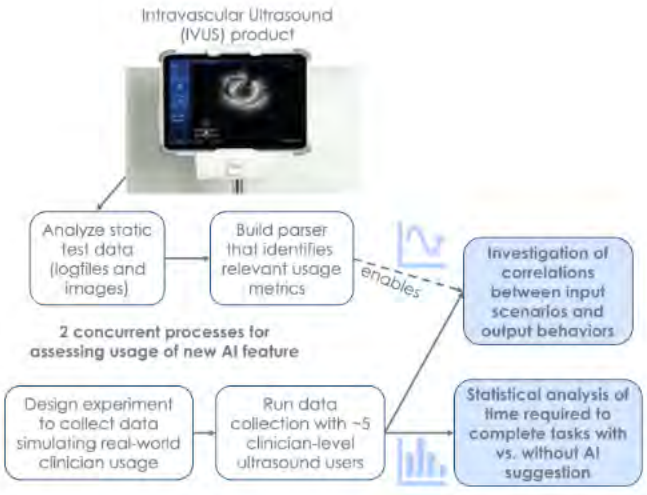
I designed and implemented a pilot study to test the impact of the AI model on user behavior, specifically on clinical outcomes and task completion times. This experiment generated Boston Scientific's first dataset mimicking "real-world" usage of the AI model during IVUS procedures. I also built a proof-of-concept software tool to enable continuous monitoring of the model and reveal data insights.

DATA SOURCES

Data for simulated IVUS workflows - anonymized case data, with images taken from real vessels - comes from older IVUS devices. The experiment used an AI-enabled development IVUS device to generate more of this data in a way that captures "real-world" interaction with the model. The IVUS devices also generate system log files that track user actions, which were parsed for the analytics tool.

Data Types and Format

The system log files are time series software logs formatted as XML. The case data includes raw IVUS image data formatted as RT files (radius-theta) and various metadata, also formatted as XML.



Author: Mercer Borris

IMPACT

The experiment generated valuable user insights, both quantitative and qualitative, for Boston Scientific to better understand how people use the AI model. The experiment data analysis demonstrates that decisions made with the use of the AI tool are slightly more optimal than those made without, though not significantly so. The analysis also reveals that the AI model contributes to significantly faster task completion times when accounting for the variability of individual testers. The software analytics tool, prototyped with experiment data, provides Boston Scientific with a blueprint for monitoring the usage and performance of artificial intelligence models in production. Without such a system, Boston Scientific can derive little value from the effort spent developing and training these models. If doctors are dissatisfied with the performance of the model, they may learn to ignore it and ultimately distrust the brand. By better understanding what factors make doctors more or less likely to use this tool, and how accurate the AI model is in a real-world clinical setting, Boston Scientific's engineers can make informed decisions about how to improve the tool and how to retrain the model. It will also enable them to track improvements over time, making sure that new versions of the model that get released via software updates actually result in a positive change.

DRIVERS

IVUS improves clinical outcomes for patients undergoing coronary procedures, but the adoption rate in the U.S. has been slow due to the difficulty of usage. Some companies are addressing this by developing AI-based assistance for medical imaging. By rigorously testing the impact of Boston Scientific's model, this project readies the company to compete in that space, ultimately improve patient outcomes, and support the maturing of AI capabilities.

BARRIERS

Timing was a barrier. Since the AI model is still an exploratory R&D project, there is no field data across different users and hospitals. Generating data with the experiment took a lot of time and resulted in a small dataset, which impacted the ability to draw statistically significant conclusions. The participants were all internal to the company and potentially biased.

ENABLERS

Situating this project in exploratory research & development enabled a lot of autonomy to design the experiment procedure and develop the software infrastructure necessary to code the software-based analytics pipeline. This six-month project was relatively immune to the timelines and regulations associated with medical devices and FDA approval. The project supervisors had the influence to help source experiment participants as well.

ACTIONS

Once I finalized the experiment procedure, I set up individual meetings with nine participants to collect data on their completion of IVUS workflows both with and without the AI tool. Much of this data collection happened at a cardiac conference that I attended in the fall. To develop the analytics pipeline, I worked with two engineers to learn the data setup, then leveraged my former engineering experience to design the software architecture.

INNOVATION

The experiment introduced more rigorous statistical control and analysis than had previously been present in user studies of the AI assistance tool. Coding the participant outcomes as 2D points, the length and diameter of the vessel area to be treated, I was able to map how "far" these outcomes were from optimal. The software pipeline introduced the team to new infrastructure tools and generated conversations that spanned the product lifecycle.

IMPROVEMENT

The experiment results show that decisions made with the use of the AI tool are 31% more optimal than those made without, though not significantly so. The AI model contributes to significantly faster task completion times (18%) when accounting for the variability of individual testers. Boston Scientific now has a dataset representing usage of this AI model and the software pipeline with insights based on that data.

BEST PRACTICES

The step-by-step experiment procedure is outlined in the thesis for anyone to replicate or adapt. The anonymized experiment data, as well as all the code used to analyze it, is available at github.com/mercerb/clinical-task-ai-assistance-experiment for anyone to download and run. Software engineers can adapt the software analytics pipeline design for AI projects.

OTHER APPLICATIONS

I encourage every company developing user-facing AI assistance models, especially those in healthcare, to run experiments that surface how human decision-making is influenced by the presence of AI. Small pilot experiments can help determine the optimal procedure for future larger experiments. Any company planning to deploy AI models should also plan for monitoring those models with a pipeline like the one architected in this project.

Driving Growth through Sales Planning, Inventory Management and Supply Chain Expansion

LFMcapital

BUSINESS PROBLEM

ShopSabre's sales are growing exponentially each year. The capacity of their external supply chain and their inventory management system have not matured at the same rate, causing an increase in customer backlog. Both the supply chain and inventory management system must expand and mature to increase throughput and decrease lead time. Key challenges to meeting this goal include (1) suppliers with high variability in timing and quantity and (2) limited inventory visibility with ad-hoc purchasing processes. ShopSabre's goal is to increase throughput by improving inventory management and growing their supply chain capacity.

APPROACH

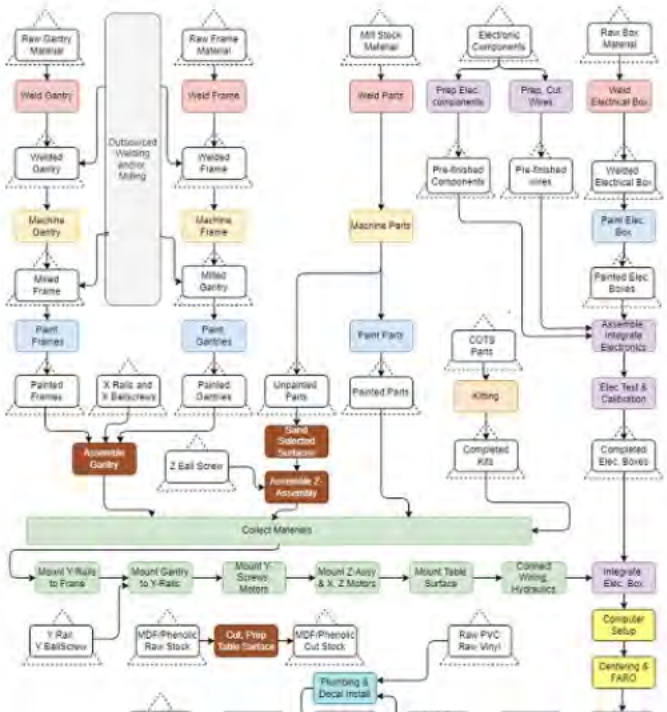
The project began by mapping the existing supply chain and internal inventory processes. Sales and Operations Planning (S&OP), inventory models, resiliency analysis, and new partnerships were then used to develop policies that expand supply chain capacity and reduce variability, thereby enabling the company to increase production rates.

DATA SOURCES

Process improvements require data about quantities and times. ShopSabre implemented an ERP system in late 2021. The researcher extracted raw ERP data and performed post-processing to generate actionable insights. The ERP system data was supplemented with observational studies ("spaghetti diagrams) and cycle time studies.

Data Types and Format

The data within the ERP system are databases that were extracted into analysis/visualization packages (e.x. Excel, PowerBI, etc).



Author: Gregory Cass

IMPACT

The combination of interventions enabled ShopSabre to increase production throughput by 3%. Employees at ShopSabre are now aligned to a single sales and operations plan enabled by a scientific inventory system and expanded supply chain network. The company's production rates are at an all-time-high and it has the business processes in place to continue growing exponentially Sales & Operations Planning succeeded in aligning different functions towards a common target. The company was able to forecast lead times in real time based on the current backlog and projected production rates. These reduced yet realistic lead times were crucial for driving sales in the holiday season of 2022. The development of an effective inventory resulted in the percentage of parts with an inventory position in the acceptable range between MIN and MAX to grow from 66% to 95%. The system also reduced variance of physical counts by 80% and percentage of parts with obsolescence risk by 10%. Supply chain expansion increased the production capacity of a critical-path component by over 92%, eliminating a production bottleneck. The expansion increased resiliency against long term disruption such that ShopSabre will no longer incur any financial impact if one supplier is disrupted. By qualifying new suppliers, ShopSabre increased its own negotiating power and was able to reduce cost of goods sold, directly increasing EBITDA.

DRIVERS

ShopSabre has a "can-do" culture that rewards action. If someone asks for help, employees are expected to drop whatever they are doing and provide assistance. The investigator benefited from this culture by being able to quickly iterate on proposed solutions with team members.

BARRIERS

The data in the ERP system was often incorrect due to data entry issues or incorrect bill of materials (BOM). For example, the system may say that the quantity on hand was five units of a part, but a physical count performed during a Gemba walk would reveal ten parts in a bin. A root cause investigation revealed the BOM assumed two parts were used on each machine when in reality there was only one. ERP data discrepancies were common.

ENABLERS

The poor performance of the existing systems for tracking inventory enabled the project to gain leadership support that drove rapid development. For example, ShopSabre had years worth of inventory for some parts while simultaneously experiencing stockouts for other parts. ShopSabre had established a Kanban system, but it was not followed rigorously to prevent stockouts. These failures were highly visible and drove the desire for change.

ACTIONS

The researcher used a structured approach to eliminate barriers to increased production throughput. The investigator documented the initial state by observing processes and learning from employees. The investigator then proposed, validated, and implemented solutions to each root cause. Finally, the investigator established systems to monitor that the intervention was producing the desired results and made adjustments as needed.

INNOVATION

A basic Min-Max inventory system requires 9 key assumptions hold (4 related to demand and 5 related to supply). All 9 of the assumptions were violated at ShopSabre. The development of a model that adjusted for these violations and delivered dramatically improved inventory performance across multiple metrics is novel and innovative.

IMPROVEMENT

The percentage of parts with an inventory position in the acceptable range between MIN and MAX grew from 66% to 95%. The reduced number of stockouts contributed significantly to ShopSabre's success in raising production throughput by 3.0% in the months following the intervention. Additionally, the variance in inventory value calculated after physical counts decreased from 3.65% prior to the implementation to 0.72% after the intervention.

BEST PRACTICES

Those seeking to replicate the solution should start with a basic model and then add complexity only where clear violations of model assumptions are identified. The complexity should be added in small, manageable blocks by working directly with domain experts at the Gemba. Additionally, utilizing a structured approach to problem solving waskey to delivering consistent results and simplifying communication with leadership.

OTHER APPLICATIONS

The proposed solution could be extended to any manufacturer of assembled finished goods. In particular, companies facing clear violations to assumptions underpinning inventory models in ERP systems, such as those faced with suppliers who deliver neither on-time nor in full.

Driving the Future of Long-Haul Trucking: Realizing the Potential of Battery Electric Vehicles

MIT Climate & Sustainability Consortium

BUSINESS PROBLEM

The MIT Climate and Sustainability Consortium(MCSC) is attempting to support companies, like PepsiCo and Holcim, to understand if and when the electrification of their long haul trucking fleets is economically and technically feasible, as well as how to establish first-mover advantage to accelerate adoption in order to achieve the overall goal of reducing company greenhouse gas emissions.

APPROACH

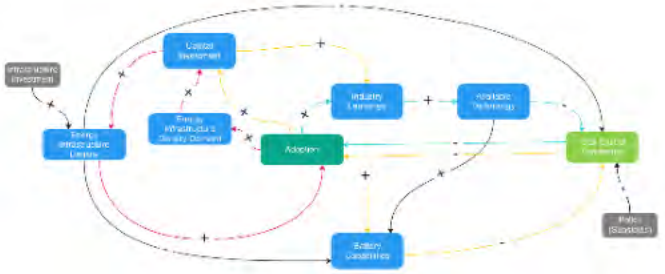
Analysis of electrification in long haul trucking will be performed to understand the need for targeted quantitative analyses to fill existing gaps and understand strategic levers to adoption and implementation.

DATA SOURCES

A majority of the data sources that are currently being used are publicly available databases, especially from government agencies or research centers. These institutions include the US EIA, EPA, DoT, Bureau of Transportation Statistics (BTS), Alternative Fuels Data Center (AFDC), North American Council for Freight Efficiency (NACFE), Atlas Public Policy, Argonne, and Oak Ridge National Lab(ORNL)

Data Types and Format

All data are csv extracts from the related website data centers. Data from tools might be extracted and saved in csv files if necessary.



Author: Natalie Chehrazi

IMPACT

The MIT Climate and Sustainability Consortium(MCSC) will be able to make strategic recommendations to companies, like PepsiCo and Holcim, around electrification in long haul trucking. This in-depth analysis will help create a framework for MCSC to understand whether electrification within long haul trucking fleets should be recommended to their partner companies. The ultimate goal is to dramatically accelerate decarbonization of long-haul trucking and to determine how and when this transition would be feasible economically and operationally.

DRIVERS

Drivers for the electrification of long-haul trucking are environmental concerns, cost reduction, and government regulation. The transportation sector is a significant contributor to global GHG emissions, and electrifying long-haul trucking can help reduce emissions. Additionally, BEVs are becoming cost-competitive with traditional diesel vehicles, and electric trucks have the potential to offer significant savings on fuel and maintenance costs.

BARRIERS

The significant barriers that impacted this project were resistance to change from companies, vehicle upfront cost differences, and charging infrastructure. Of these challenges, resistance to change will be the most difficult to overcome as upfront cost will reduce and technological developments will lead to increased range or implementation of more charging infrastructure.

ENABLERS

This projected was enabled by the teams willingness to understand whether electrification was feasible. This reduced resistance within the team because the project was focused on if and where electrification of long-haul trucks could be feasible, rather than trying to force electrification to be the emissions reducing technology in this space.

ACTIONS

To understand the feasibility of this technology in the long-haul trucking space the following analyses were performed: general industry analysis, system dynamics analysis, total cost of ownership analysis (nominal and sensitivity analysis performed), net present value analysis, and emissions reduction analysis. These analyses allowed us to determine whether electrification was feasible and under what economic scenarios it would be beneficial.

INNOVATION

The sensitivity analysis performed for the total cost of ownership analysis was innovative. This analysis demonstrated at what costs, distances, and fuel economies electrification is no longer an economically feasible option. These threshold were then compared to economic and energy projections which demonstrated the probability of electrification not being feasible.

IMPROVEMENT

A comprehensive understanding of the factors influencing the adoption rate of BEVs for long-haul trucking and offers practical recommendations for accelerating the transition to BEVs in this industry. The results of the system dynamics, environmental, and financial impact analysis indicate that the transition to BEVs is favored from various perspectives especially if development in charging capabilities reaches 500 kW.

BEST PRACTICES

The best practices that one should use is the different forms of analysis. Although they are extremely conservative estimates they provided a great foundation for the case for electrification. It is recommended that they perform the total cost of ownership analysis, net present value analysis, and emissions reduction analysis. For all analysis the different economic and performance scenarios outlined should be utilized.

OTHER APPLICATIONS

This approach can be used to evaluate the economic feasibility of any technologies that are attempting to replace old unsustainable technologies.

Production | Aerospace and defense | Improved process performance | Network analysis

Improving Factory Performance through Controlled Order Release

BUSINESS PROBLEM

Boeing Fabrication is composed of 12 different business units with different sources of demand and different manufacturing characteristics. Demand is mainly generated by an MRP system that schedules operations backwards from a customer delivery date based on standard work times. The resulting scheduling processes result in a high degree of variability on the shop floor with respect to flow times, WIP levels, and use of available resources. Fabrication is looking for a way to stabilize the load on the shop floor so that system health can be tracked against an achievable output target.

APPROACH

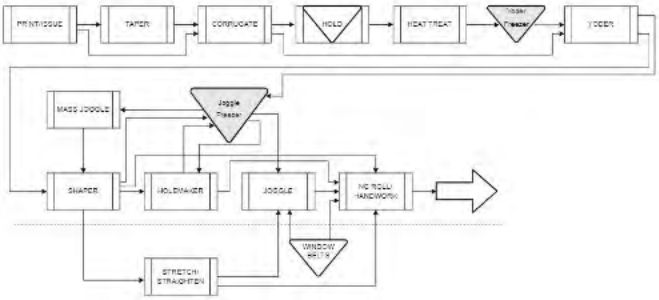
I started by measuring through interviews, observations, and data visualization to understand how operations are planned by IEs and executed on the shop floor. I also assessed how those realities benchmark against best practices. Then I worked with the shop to implement processes to release work at the rate orders were completed while creating visibility of the shop's schedule position.

DATA SOURCES

The data architecture at Boeing has been slowly built and modified over many years. There is a complex interconnected system of data warehouses, web-based and server-based folders, enterprise programs, and locally developed visualization tools.

Data Types and Format

Teradata: SQL with operation completion and direct labor charging. ERPMart: SQL with demand, material, and plan information. Production Artifacts: Various local tools developed for production control.



Author: David D Covell

IMPACT

The proposed solution has the potential to fundamentally change the way that the schedule is consumed. Current metrics are focused on how closely operations are being completed relative to when the schedule says they should be. The solution is focused on how closely operations are being completed relative to when the schedule says they should be. The solution is focused on ensuring throughput is matched to the demand placed on the factory, and in the event that throughput is not able to keep up prevents WIP from backing up onto the factory floor. If fully implemented, the business would pivot from being a push-oriented company to a pull-oriented company. It would also decrease the load on controlling the company's many factories, as they only have to directly manage a handful of critical operations instead of every individual operation per factory.

DRIVERS

A common refrain on the shop floor was that there was too much variability in order routings to be able to effectively control. I also saw a cyclical buildup of WIP on the shop floor to levels that overloaded some areas and caused work stoppage in others. Together, this indicated to me that a method for limiting total WIP which doesn't explicitly control location of work orders within the system could be effective.

BARRIERS

The metrics used to track and manage operations incentivized the over-release of orders and of processing orders before downstream operations were ready to receive them. Additionally, decision making for order processing once orders were released was decentralized and effectively left to operator discretion. Finally, an aversion to change combined with the lack of a clear change impetus limited the effectiveness of the project.

ENABLERS

My team's trust provided me freedom to recommend a somewhat unorthodox method for changing the way that work was released. Their willingness to try something new that promised tangible benefits helped ensure that the recommendation was implemented on the shop floor. The managerial support ensured that I had the mentorship and backing necessary to keep the project progressing at a consistent rate.

ACTIONS

I conducted database queries and data transformations to gain a clearer view into how work traveled through the system. I worked closely with subject matter experts to develop a process that supported their current statement of work. I spent a significant amount of time working with individuals on the shop floor to gain their insight into daily operations, their feedback on the developing solution, and garnering support for the final solution.

INNOVATION

Instead of replacing the schedule completely in the implementation of CONWIP, the schedule was used to set relative priorities for work in queue. Schedule data for the bottleneck process could then be used to determine when to optimally employ overtime in order to meet throughput requirements.

IMPROVEMENT

Average WIP level in the shop was reduced by 27%. Average cycle time was reduced by 1.2 days per order. Orders completions improved from an average of 0.5 days late to schedule to 0.4 days early to schedule. Productivity on the capacity constrained resource increased by 13%.

BEST PRACTICES

Definitively identify which operation or set of operations are the system bottlenecks. Ensure that you have a robust method for determining how much work has been completed and processed out of the system. Identify an intermediate point between the level of WIP that currently exists in the system and the minimum required to feed the bottleneck daily. Finally, ensure all affected parties are included in designing the new process.

OTHER APPLICATIONS

This solution is useful in any manufacturing environment that has a high quantity of variability in routing, product mix, or both.

Operations | Telecom | Network optimization | Network analysis

SustainabilityAnalytics– Meeting Carbon Commitments most Efficiently

BUSINESS PROBLEM

With the increased prevalence of energy compliance laws coming into effect in cities and states across the US in the coming 10 years, companies must reduce their real estate energy consumption to be compliant with emissions standards and avoid fines. Verizon owns and operates thousands of buildings, many of which are central offices (COs) which consume large amounts of energy to maintain network transmission effectively. A wide range of energy efficiency upgrades are possible for each central office, but there is a finite amount of time, resources, and capital available. Upgrade options must be prioritized optimally to maximize impact.

APPROACH

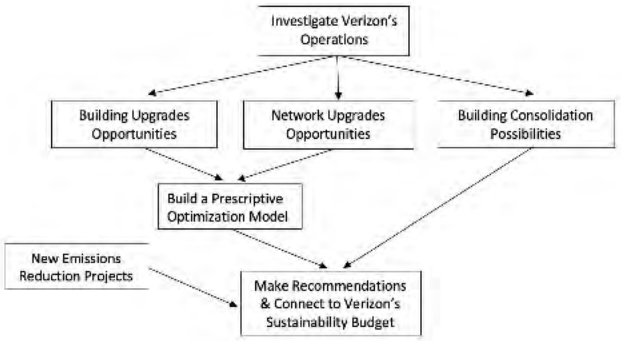
I broke down how energy consumption could be reduced across Verizon's real estate into 3 categories: energy efficiency upgrades, energy consumption reduction, and real estate consolidation. For each category I engaged with primary stakeholders on what factors needed to be taken into account to make accurate decisions. These were utilized as primary inputs for an optimization model.

DATA SOURCES

Verizon has time series energy consumption data across their building portfolio dating back to 2018 which will be used to establish trends for consumption over time to quantify potential impacts of upgrades. A list of potential building retrofits that improve energy efficiency, with their associated capital and energy savings, is available from both the real estate and network teams.

Data Types and Format

Time series available in SQL type DBs accessible online or through csv download. Building metadata and building audit data in excel spreadsheets.



Author: James Donegan

IMPACT

There are three areas of impact that resulted from this project. Our first area of impact is a result of the output of our final optimization model where we see that an optimization model built to reduce energy spend for Verizon can result in a 14% reduction in energy costs and an 18% reduction in emissions for the company's NYC baseline location. With these savings scaled to a national level for Verizon's operations, this model's implementation would cause a 7% reduction in Verizon's entire scope 1 and 2 greenhouse gas emissions by utilizing a prescriptive optimization framework to decide what building and equipment upgrades to carry out for energy savings. These nationally scaled energy savings sum to >$200 million. The next area of impact looks at alternative solutions to meet Verizon's net-zero goals that have a reduction in emissions, to complement both building upgrades and the existing method of financing VPPAs for renewable energy credits. We find that if Verizon's sustainability budget was restructured and distributed to a variety of emissions reduction projects, a 60% reduction in emissions is possible for the same cost per ton of CO2 that Verizon is currently spending. Our final area of impact highlights the financial and sustainability opportunities available from the consolidation of central offices in high-population-density metropolitan areas. These opportunities sum to billions of dollars of savings for Verizon and significant reductions in emissions.

DRIVERS

The introduction of environmental compliance laws across the US over the coming years was the main driver for this project. The first of these laws is Local Law 97 in NYC, which fines building owners for exceeding pre-determined emissions limits. Verizon owns and operates 68 high energy consuming central offices in NYC. Identifying how to minimize the negative financial impact of LL97 on Verizon's operations was the main driver for this project.

BARRIERS

The largest barrier that impacted the project was related to data. An abundance of data was available for the project to build out the optimization model, but much of the buidling upgrade effects on efficiency were based on predictions from energy auditors rather than from real operational data. Ideally the model would be maintained by Verizon to include a feedback loop of actual upgrade accuracy to improve model efficacy.

ENABLERS

Albeit an incredibly large company, the people and teams within Verizon genuinely care about measures to reduce emissions from the company's operations. Once we were able to identify goals of saving money while also reducing emissions, it was easy to gain support across teams within the company, which made obtaining data much easier.

ACTIONS

Much of the early stages of the project, in advance of building the optimization model, was spent conducting significant stakeholder engagement. This process was particularly helpful as it provided information on how Verizon's operations between its real estate and network teams were intertwined. Both had their own performance metrics, and an important aspect of this stage of the project was leveraging these metrics towards inputs for model.

INNOVATION

The area of my project investigating the impact of central office consolidation was one of the most innovative aspects of the project. The decision to consolidate buildings' operations into one another was not something that was deemed suitable to build into an optimization model. Instead, we identified where potential groupings of central offices were that could be consolidated and the impact of each building on both bottom line and emissions.

IMPROVEMENT

The optimization model provided a project management tool that could lead to a 14% reduction in energy costs, and a 18% reduction in emissions for Verizon's NYC central office portfolio. We also show a path to net-zero with a 60% reduction in actual emissions through restructuring Verizon's sustainability spend. Lastly, we quantified the potential billions of dollars of savings through central office consolidation in New York City alone.

BEST PRACTICES

Build a well structured data dictionary for all input data. This process was invaluable for this project as all necessary information was stored in a single location, making building and editing the optimization model much easier.

OTHER APPLICATIONS

The optimization model and its three dimensional binary decision matrix is directly applicable as a planning tool where time and location need to be taken into account, as well as an event. In our case this event was a building upgrade for a given building in a given year. An example of how this could be applied in a different context would be as simple as a university program class scheduling tool to minimize walking distance for students.

Supply chain planning and inventory management | Industry components | Supply network connectivity / performance | Network analysis

Make vs. Buy Optimization for Industrial Manufacturing & Distribution Business

American Industrial Partners

BUSINESS PROBLEM

Optimas is uniquely positioned as both a distributor and manufacturer in the global fastener industry with ~50 distribution centers and 2 manufacturing sites (US & UK). Increased end market volatility, raw material scarcity, and global supply chain challenges have resulted in a ballooning portfolio of suppliers, elevated inventory levels, challenges serving customers. Optimas is seeking to develop the methodologies, tools, and processes to optimize its supply base to appropriately leverage its internal manufacturing capabilities & capacity and rationalize its portfolio of suppliers in a sustainable & recurring fashion.

APPROACH

This project developed a framework and decision support tool for optimizing make vs. buy decisions in Optimas' business context. A strategic framework incorporating supplier strategy, internal & external supplier capabilities, internal capacity, and total cost was built to identify, qualify, and validate opportunities.

DATA SOURCES

Recent distribution data at Optimas became increasingly available following a 2021 ERP transition, although data across new & legacy systems remains disconnected although generally available. Manufacturing data exists in a separate ERP/MES system. The researcher worked to combine, augment, and validate data sources in novel ways to support research efforts and implementation.

Data Types and Format

Data is contained in new & legacy distribution & manufacturing systems, a web-based supplier portal, Tableau reporting, and offline Excel spreadsheets.

Author: Nick Esposito

IMPACT

The impact of this project is threefold on Optimas' business. First, the effort quantified the total addressable market for external threaded fastener insourcing and outsourcing. Second, the project identified an initial prioritized set of insourcing opportunities representing ~20-30% of the total addressable market. Finally, the decision support tool developed will aid Optimas in tactically evaluating and executing on make vs. buy decisions.

DRIVERS

This project was initially motivated by three main factors: increased uncertainty of global supply of products, increased inventory due to the bullwhip effect in customer demand from the COVID-19 pandemic, and a desire to improve business profitability. Additionally, Optimas wanted improve strategic coordination between internal manufacturing and the Supply Chain organization.

BARRIERS

Barriers to the project's success included a challenging data landscape due to an ERP transition prior to this effort and differing views among senior management at Optimas and AIP on the value of internal manufacturing.

ENABLERS

Enablers to the project's success included a reorganization of the sourcing team centered around product categories, strong manufacturing data on production costs and capacity that could be extrapolated to new parts, and enthusiastic support from senior leadership to make improvements to the supply chain.

ACTIONS

The make vs. buy strategy was developed in collaboration with key stakeholders at Optimas, backed by available data. This strategy was then translated into an SKU-level decision support tool with the help of the Business Intelligence team and published. Feedback was solicited from users and incorporated into revisions of the tool.

INNOVATION

One of the more innovative aspects of the decision support tool was the novel combination of siloed datasets to produce an at-a-glance decision support tool that embodied the make vs. buy strategy in quantitative and qualitative ways.

IMPROVEMENT

The final improvements that the make vs. buy strategy and decision support tool provided were: quantification of the total potential of insourcing/outsourcing in the external threaded category, a prioritized list of SKU-level opportunities totaling approximately 20% - 30% of the total opportunity, and a method for identifying additional opportunities at the SKU level.

BEST PRACTICES

Best practices include: utilizing quantitative data at the backbone of strategy development where possible, leveraging live data connections wherever possible to minimize the costs of refreshing data-based tools, and including key stakeholders throughout the development process to minimize rework.

OTHER APPLICATIONS

Similar strategies and tools could be developed for similar organizations that manufacture and distribute commoditized products (e.g., purchase or produce complete parts for distribution) by utilizing strategic sourcing best practices and bringing together organizational data in a novel way.

Operations | Healthcare / Pharmaceuticals | Improved process performance | Linear / Non-Linear

Ship-Pack Optimization to Minimize Fulfillment Costs from Manufacturing to Customer

BUSINESS PROBLEM

The motivation for this project is to reduce operational expenses, distribution center complexities, and improve customer satisfaction by aligning manufacturing and distribution efforts with customer needs. This thesis centers around the potential of ship-pack optimization to minimize costs across the distribution chain.

APPROACH

Through conversations with "ResMedians" and external partners from manufacturing to customer service and by analyzing ResMed's past year fulfillment of 2M customer orders for 80M products, the project developed a model for case-pack optimization. The optimization model uses costs from labor, shipping, customer call to serve, and packaging. The decision variable is the ship-pack quantity for a SKU.

DATA SOURCES

The primary data source is held in ResMed's cloud service and includes customer order numbers, customers, shipping zip codes, number of SKUs, time between ordering and shipment, and revenue. Other sources include excel sheets containing packaging configurations for each SKU and customer complaint data tied to each customer order.

Data Types and Format

Customer order data is held in tables in ResMed's cloud service or excel. Site visits, interviews, and time series studies were generated manually and refined in Microsoft Office tools.

Author: Avery Fullerton

IMPACT

The optimized ship-pack cost-to-fulfill model finds that ResMed can save over 5% or over $2M dollars, by optimizing ship-pack quantities. The bulk of this cost savings is in minimizing multiple shipments of product and reducing labor costs at the distribution centers. Interestingly, some SKUs increase in ship-pack quantity, while some SKUs decrease in ship-pack quantity. This is expected, as there is a balance between larger packages saving costs at the manufacturing site, and reducing the freight base costs, but incurring larger costs due to distribution center handling. An additional study was conducted using the cost-to-fulfill model. This study analyzed customer ordering behaviors and sought to identify operational cost savings by influencing customer behavior. This motivation led to the creation of a secondary model; the optimized ordering cadence cost-to-fulfill. ResMed stands to gain operational savings of over 9% or over $4M dollars if all customers were to move to a weekly ordering cadence.

DRIVERS

The project charter was to identify opportunities within ResMed Commercial Operations to: 1. Increase customer satisfaction 2. Reduce ResMed costs 3. Increase revenues. Through conversations with "ResMedians" across Operations, Customer Service, Distribution, Finance, Logistics, Manufacturing, Marketing, Product Engineering, Pricing and by analyzing ResMed's past year fulfillment of 2M customer orders, case-optimization became a clear solution.

BARRIERS

Barriers that impacted the project mostly focused on the lack of data tied to shipping. There does not exist a way to tie individual orders to freight terms. Therefore, generalizations were made on the averaging of freight costs. These estimates were validated as the model was matched to known freight costs for the fiscal year.

ENABLERS

The culture at ResMed and continued appetite for data was a major enabler. The Commercial Operations team, led by Anthony Vargas, was always willing to lend information, share their network, or provide a brain-storming session to solve problems. Additionally, ResMed's external partners were key enablers to understanding the entire distribution chain.

ACTIONS

The results and approach of this thesis was presented to senior leaders within ResMed. The results found a receptive audience. ResMed is actively looking for opportunities to optimize customer ordering behaviors. The results of this internship on current operations remains to be seen.

INNOVATION

The cost-to-fulfill model created in this thesis is novel to literature. The model is capable of recommending ship-pack changes based on manufacturing packaging costs, transportation costs, handling costs, distribution packaging costs, and customer complaint costs for real-world demand. This model, unlike most in this area of research, is unique to a company primarily operating as a distributor of their product, rather than a two-echelon system.

IMPROVEMENT

The optimized ship-pack cost-to-fulfill model finds that ResMed can save over 5% or over $2M dollars, by optimizing ship-pack quantities. ResMed stands to gain operational savings of over 9% or over $4M dollars if all customers were to move to a weekly ordering cadence. The bulk of this cost savings is in minimizing multiple shipments of product and reducing labor costs at the distribution centers.

BEST PRACTICES

Someone who would like to replicate this solution must engage the entire distribution chain. This includes but is not limited to Commercial Operations, Customer Service, Distribution, Finance, Logistics, Manufacturing, Marketing, Product Engineering, and Pricing. Additionally, any solution will require access to real-world customer ordering data.

OTHER APPLICATIONS

This solution can be generalized to any distribution chain for a supplier of product that is shipping multiple items in one packaging solution. This thesis is of special interest to suppliers who see a mismatch between case pack quantities at their manufacturing site and customer's typical order quantities.

Product design / development / engineering | Oil and gas | Network optimization | Classifiers

INTEGRATED ENERGY MODELING TOOL FOR ELECTRIC AND GAS INFRASTRUCTURE DECISION SUPPORT

nationalgrid

BUSINESS PROBLEM

As National Grid lays out their roadmap to achieve net zero emissions goals by 2050 a major issue is the complete reduction in usage of natural gas. There are many opportunities available to reduce natural gas usage, however the four most prevalent for National Grid in this area are: Geothermal Heating, Renewable Natural Gas, Heating Electrification, and Hydrogen Blending. The problem for National Grid is knowing where each technology should be used to minimize costs to the end user and still meet all heating demands.

APPROACH

The initial approach is to determine current capacity to support electrification or hydrogen blending. Following will come a cost analysis for each technology in each area. Then, we'll analyze thermal capacity vs. cost for each of these options. All data will be compared in a case study format for two cities.

DATA SOURCES

Existing data was limited to gas network mapping for New England and New York. Additionally, mapping of Leak Prone Piping (LPP) was included as well as pressures required for each area to achieve peak heating needs.

Data Types and Format

Data is in numerical format via Excel sheets as well as GIS shape files for network layout and ratings.

Author: Frankie Galindez de Jesus

IMPACT

A step-by-step integrated (electric and gas) approach to determine the cost to customer for both electrification or hydrogen blending. Allowing the company to take this factor into consideration when determining how they will lay down their decarbonization strategy.

DRIVERS	There is a large push for decarbonization of the heating industry by 2050, and one of the many factors that go into rate cases is how a shift in company operations/expenditures will affect the customer. So the solution lies within how can we minimize impact to the customer while still proceeding to meet our net zero goals.
BARRIERS	Lack of readily available research on hydrogen blending in excess of 20%, difficulty in quantifying risk given that research in the area needs improvement. Difficulty generalizing costs given major differences in technology and areas where they may be utilized.
ENABLERS	The team which the company placed me on was an integrated team, both National Grid electric and National Grid gas. This infrequent occurrence allowed for quick resolution of questions from both sides of the company, allowing for better comparison of data/strategy. Especially with regards to electrification.
ACTIONS	The solution has not been implemented but is under review by the company.
INNOVATION	Having full access to company gas and electric data allowed for an actual comparison of true gas send out with true electric loading. Allowing for, given the heat loading assumptions utilized, true estimates of cost for electrification.
IMPROVEMENT	It provided the answer to which decarbonization of heating strategy results in lower cost to the customer for two cities in the region of study.
BEST PRACTICES	Ensure integration of both sides of the utility (if it serves both arms) to enable true data access and minimize assumptions. Additionally, invest more time in the regulatory processes behind rate case determination.
OTHER APPLICATIONS	Similar methodology could be applied to compare other decarbonization of heating technologies such as renewable natural gas (RNG) or networked geothermal.

Operations | Retail | Warehousing automation / flow optimization | Network analysis

Innovation Process at Omnichannel DCs Undergoing Shifts in Channel Mix

BUSINESS PROBLEM

Nike has been experiencing accelerated growth in digital demand (peak growth of potentially up to +40% in units through the DC network). Their omnichannel DCs, previously setup to support large wholesale orders, currently lack the throughput capacity to support this shift in channel mix. This shift comes with other marketplace challenges such as labor reliance, sustainability, fulfillment cost, and delivery speed. To address these current business trends, this thesis proposes an end-to-end process for innovation within the four walls of an omnichannel DC that will recommend the best innovation in the right areas of the DC.

APPROACH

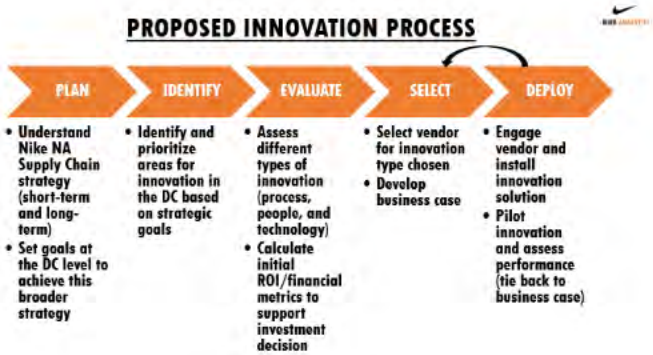
The proposed innovation process was developed using data gathered from interviews and research on Nike's internal innovation processes and external innovation processes. The process was then evaluated using a past successful project at a DC to see if it could recommend the same innovation. The process was then applied to the same DC today to recommend what innovation they should pursue next.

DATA SOURCES

Interviews with stakeholders across the company; On a monthly basis: expected capacity (based on labor and efficiency metrics), demand forecasts, shipment actuals; Recommended vendor lists for automation solutions; Financial metrics related to DC performance; Historical automation project business cases and performance tracking

Data Types and Format

Interviews (notes, audio); Excel files; SQL databases/tableau dashboards; PowerPoint presentations; Word files, Power BI models



Author: Fiona Gouthro

IMPACT

This process will allow Nike to address the right constraints within their DC network in a systematic and consistent way. When following this approach to innovation, the expected outcomes are: 1. Capacity - increase in the DC network through improved productivity efficiencies and enhanced performance to meet demand. 2. Labor - reduced reliance on seasonal workforce during peak months and unfulfilling manual labor. 3. Efficiency - drive to simple, flexible, and scalable solutions that eliminate waste and non-value-added activities. 4. Sustainability - reduced cost through execution of sustainable packaging and shipping solutions. 5. Human Factors - development of innovative solutions that are simple, safe, and create meaningful work for labor workforce.

DRIVERS

Main driver is to increase DC network capacity due to increase in digital demand (change in DC channel mix). There are secondary drivers to reduce reliance on temporary labor during peak seasons, to reduce costs, to improve efficiency, and to improve sustainability.

BARRIERS

Nike is a matrixed organization with multiple stakeholders involved in investment decisions. This results in conflicting incentives and challenges when getting 100% buy-in on a new innovation decision. Nike is also currently focused on expanding their distribution network through the addition of new nodes instead of investment in their current assets.

ENABLERS

All stakeholders have been very receptive and willing to provide information and data to enable my project. DC performance is becoming increasingly important to the company.

ACTIONS

My recommended solution to begin executing a project at the DC could not be implemented in the 6 months I worked at the company. Instead, I was able to roll out the process across multiple teams and discuss how my work could be applied after I left the company.

INNOVATION

The capacity model built during the course of this project allowed for users in the DC to update capacity models themselves and presented visualizations that were more intuitive to a less experienced user. The simplicity of the process itself can also be seen as innovative.

IMPROVEMENT

The final improvement that my solution provides is a structure that will recommend the best innovations for the problems that the DC will face. I am also leaving the DC with an updated capacity model of their most complex DC and a greater sense of connection between WHQ and DC teams.

BEST PRACTICES

When building an innovation process, always include a planning/goal setting phase at the beginning of the process that defines the company's strategic goals for the innovation. Analyze the specific company that your process is being built for - a renewed analysis on the company's existing processes and culture is needed to maximize adoption.

OTHER APPLICATIONS

This process for innovation/automation should be scalable to use at any DC or at a broader network scale within Nike.

Operations | Consumer electronics | Cycle time optimization | Deterministic / Stochastic

Development of a Student Operated Production Facility using Discrete Event Simulation and Continuous

AMERICAN INDUSTRIAL PARTNERS

BUSINESS PROBLEM

Technological advancements have outpaced lagging industry training programs, resulting in an ill-equipped workforce incapable of matching stride. A dedicated subgroup of researchers from MIT's Device Realization Laboratory is currently developing a dual-purpose desktop Fiber Extrusion Device (FrED) that has the potential to revolutionize industrial manufacturing training programs and significantly increase the speed to market for advanced fiber extruder designs. The group plans to implement FrED into training programs for high school, college, and industry students by manufacturing the devices themselves and working with industry partners.

APPROACH

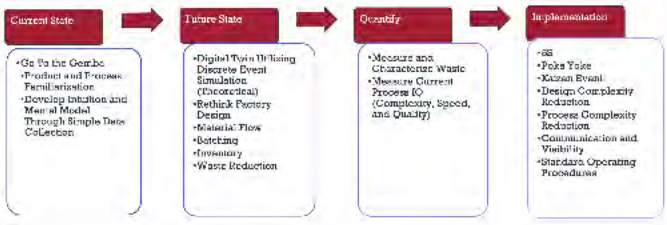
The research takes a holistic and systematic approach guided by lean manufacturing philosophy. My approach recognizes the importance of global optimization of a system. It seeks to balance local improvements with the global objective of maximizing factory throughput by reducing production takt time and prioritizing operational excellence, aiding in the on-time delivery of quality parts.

DATA SOURCES

Cycle times were available for 3D printed parts and were collected from slicing software, but setup, calibration, and maintenance times have not been studied. Statistical data for processes was non-existant and heuristics were used for the discrete event simulation. Part costs were available in an excel spreadsheet from a previous project.

Data Types and Format

The project files created from slicing 3D printed parts contain the settings used and the processing times for the parts. They are formatted as 3MF for PrusaSlicer or Cura Slicer project files.



Author: Logan Greene

IMPACT

This project aims to support the DRL in advancing the development of FrED and the FrED Factory, accelerating the production and delivery of an educational tool that addresses the skills gap in smart manufacturing. Utilizing a data-driven approach to improvement, the research aims to implement sustainable changes supporting the FrED Factory's long-term success. To achieve this goal, the project will establish an operational excellence framework, devise methods for factory performance analysis, and facilitate a "Kaizen" event that simplifies and accelerates a technical manufacturing process. Through a comprehensive analysis, the research will deliver practical solutions for improving the factory's design, enhancing standard operating procedures, producing first-pass quality parts, optimizing inventory management, and creating a digital twin of the factory to bolster operational efficiency. While the proposal is customized for the unique requirements of a student-operated and -managed factory, the concepts and methods derived from lean manufacturing principles can be applied to any organization. Overall, the objective of the project is to significantly contribute to the DRL's mission of providing high-quality, practical education for individuals seeking to enhance their knowledge of smart manufacturing.

DRIVERS

The conditions of the factory violated many of the core principles of Lean, prompting the need for intervention. Clutter obstructed visual cues that could be used to proactively identify potential problems. A lack of organization and improper storage practices resulted in critical tools or parts going missing. The disarray created hidden factories, generating waste, and hindering productivity and efficiency.

BARRIERS

The factory was not running throughout the entire duration of the project. Prior work in the FrED Factory has been documented in academic papers and internal laboratory documents, but significant operational information has been lost due to unsustainable file management practices. Performance data on factory operations, such as machine failure rates, processing times, and throughput analysis, is unreliable or unavailable.

ENABLERS

In January of 2023, I created project proposals and submitted them to the MIT Undergraduate Research Opportunities Program Office (UROP) for the Individual Activities Period (IAP) and the Spring semester. I interviewed eight undergraduate candidates and hired 5 of them to work on projects related to process and product improvement in the laboratory. I managed their projects and mentored them throughout, concluding with a final presentation.

ACTIONS

I created an analytics tool using discrete event simulation to access factory performance once data is collected. I conducted 5S by coordinating with facilities to remove broken or unused equipment, removed trash, cleaned, organized, and created standard operating procedures for the 3D printing farm. I mentored students and managed their projects. I collected data on the 3D printing farm, and implemented solutions to improve uptime.

INNOVATION

The discrete event simulation was hard-coded using the simpy library in the python language. The simulation accounts for stochastic events, implementing random machine failures and worker disruptions. In addition, a kinematic mount was developed for the 3D printer build surface to improve repeatability and quality. Firmware options were explored for the printers and the firmware was customized to improve speed, automate, and reduce failures.

IMPROVEMENT

The cycle time to produce all of the 3D printing parts for 1 FrED decreased 34%, from 877 to 571 minutes. Excluding setup time, if the 3D printers worked 24 hrs a day without failure, the printers were only able to produce enough parts for 1.64 FrED's a day. Now, the printers are able to produce 5.06 FrED's a day. Part failures were reduced and part quality was improved through vibration reduction and improvements in repeatability.

BEST PRACTICES

The approach, solutions, and implementation are applicable to any organization. Although the FrED Factory is unique, a systematic methodology was used to identify problem areas, quantify initial conditions, implement solutions, analyze performance, and iterate. Development of basic processes is essential to creating a baseline to determine future courses of action.

OTHER APPLICATIONS

Discrete event simulation (DES) is a powerful modeling technique that allows you to analyze complex systems by simulating the individual events

Operations | Healthcare / Pharmaceuticals | Supply network connectivity / performance | Ranking Systems

Improving Supply Chain Resiliency through Single-Use Aseptic Connector Alignment and Standardization

BUSINESS PROBLEM

Over the last decade, the adoption of single-use systems (SUS) for biomanufacturing has expanded industry-wide and within Amgen. With the current supply chain disruptions brought about by the pandemic and the explosion in demand from vaccine manufacturing, continued supply of SUS was deemed high-risk for Amgen. There are over 600 SUS assemblies routinely sourced for continued production. With aseptic connectors standardization, we are looking to reduce the number of assemblies while also enabling network transferability of parts across Amgen's sites, potentially alleviating the supply disruptions and improving supply chain resiliency.

APPROACH

To assess the feasibility of standardizing aseptic connectors across Amgen, a current state assessment along with a business case will be developed, outlining the benefit, cost and risks of the change in existing Amgen sites and a new plant in North Carolina. Industry benchmarking and supplier discussions will also be included. Lastly, an implementation plan will be proposed.

DATA SOURCES

Various data from Amgen's existing systems and workstreams are necessary. Input on resources and time required to enable the change will be collected from the cross-functional SUS network team and site technical leaders as key stakeholders. Data on single-use assemblies and process setups are documented in PLM and internal documents. Spending and inventory information are captured in SAP.

Data Types and Format

• Excel data of various assemblies from PLM library • Excel data of spend, inventory, and cost from SAP • PDF copies of process documents • Survey and verbal input from key stakeholders and suppliers

Current State Analysis

- Analyzing the best candidate connector for standardization based on:
  - Technical specification
  - Supply robustness
  - Reliability
  - User experience
  - Peer benchmarking data

Cost-Benefit-Risk Assessment

- Assessing the costs, benefits, and risks of Amgen's options related to standardization
  - Do nothing
  - Standardize to two connectors
  - Standardize to one connector

Implementation Plan Proposal

- Proposing a feasible implementation plan given the constraints highlighted in the prior assessment

Author: Toni Guiriba

IMPACT

This project aims to strengthen the supply resiliency of Amgen's single-use assemblies which are interconnected for production using aseptic connectors. Cross-sharing of parts and collaboration across the network are currently hindered by varying aseptic connector preferences across the sites. By doing a thorough assessment of the various connectors, we hope to select the best option for standardization that will minimize the supply risk for Amgen while maximizing technical performance, quality, and user experience.

DRIVERS

Standardization of single-use assembly designs has long been discussed across the industry and at Amgen. In midst of the COVID-19 pandemic supply disruptions, this improvement became more salient as Amgen evaluated ways to improve their supply resilience. Standardizing aseptic connectors allows network transferability of parts, enabling greater supply chain collaboration and coordination in the event of supply disruptions.

BARRIERS

The lack of tangible and quantifiable data to support the benefits of the change along with anecdotal evidence was challenging for justification and support of the change. Meanwhile, cost and effort associated with a comprehensive standardization was too significant.

ENABLERS

This project was made possible through the support of Amgen's functional single-use network team, engineering technical authority, and site technical leads. Each stakeholder provided valuable information from both the network and individual site level, ensuring a balanced and thorough assessment.

ACTIONS

The assessment was informed by stakeholder interviews, data analysis on current usage and defects, survey of manufacturing associates, supplier reach-out, and peer benchmarking. All connectors were evaluated based on technical specification, supply robustness, user experience, and reliability. The costs, benefits, risks of the various options for standardization led to a recommendation to implement in a phased approach.

INNOVATION

The project defines a systematic approach for assessing the best option for standardization of a manufacturing component.

IMPROVEMENT

Standardization improves network transferability, supply robustness, economies of scale, and user experience. It also reinforces a culture of improvement as well a company's competitive position as a leader in technological innovation and continuing best practices.

BEST PRACTICES

Take available data and analyze the origins to determine if they reflect reality and contain the necessary information required for the assessment. Supplement the data with the voice of all stakeholders and customers, including the manufacturing associates who have extensive experience working with the connectors.

OTHER APPLICATIONS

This approach is applicable to manufacturing parts that need standardization across processes and plants to streamline sourcing and improve supply resiliency.

Operations | Healthcare / Pharmaceuticals | Predictive forecasting | Deterministic / Stochastic

Scenario Analysis of Profitability through Simulation of Different Business Contract Models

AMERICAN INDUSTRIAL PARTNERS

BUSINESS PROBLEM

This project focuses on how best to scale sales in healthcare industry through new partnerships with retailers. Profitability in a region in this industry is highly dependent on state-specific healthcare reimbursement structure, freight, & fulfillment. This research will answer the business question of what contract agreements with retailers would be most profitable for both parties.

APPROACH

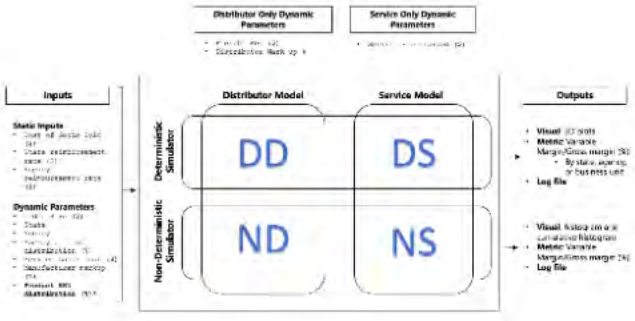
First, the cost drivers and the reimbursement structure was modeled for healthcare sales. Two possible contract models, distributor and service model, were built with dynamic parameters. A simulator was used to plot the results of deterministic variations in model parameters. The Sobol sequence was used as a quasi-Monte Carlo method to capture stochastic variables in the model such as demand.

DATA SOURCES

From the business direct to consumer data, there is data on demand, revenues, orders, quantity of items shipped, freight, reimbursement rates, and labor costs. From retailers, there is data on current fulfillment costs capacities via traditional channels. There is also cross industry shopping data from retailers which can serve as a basis of assumptions for a demand forecast.

Data Types and Format

Most data is numeric, categorized by state, and provided over a period of time. Due to anomalies in 2020 due to COVID-19, the past year is the most indicative regarding demand, freight, and labor.



Author: Lauren Heintz

IMPACT

This solution produced 4 model-simulator combinations with accompanying 3D visualizations of the results. Through the deterministic simulator outputs, the user (business person), can look at a wide range of possible profitability outcomes. The outcomes (variable margin) are based on chosen input contract parameters. This provides the decision-makers and those writing the contract with more visibility on the most important factors. The stochastic simulator also provides results which can be viewed as a distribution of possible outcomes. This starts to shed light on variation between the low, average, and high pay out outcomes. This helps characterize uncertainty and again inform future contract decisions. This might inform not only which contract to choose, but which parameters in the contract might be best to be flexible year by year(for example. based on demand realization).

DRIVERS

Inflation, raw materials, freight, labor shortage. Healthcare provider consolidation, value-based care initiatives. Trends in retail & healthcare merging.

BARRIERS

Lack of data for industries and products that are new. Difficulty in obtaining data for new fields to research to enter. Challenges working out partnerships with a high degree of shared ownership over the product. Working on digital projects across multiple organizations was new in this company, and difficult to project manage.

ENABLERS

Small teams with easy access to executives, small but capable business intelligence team in place, in-person office presence sped up the learning curve

ACTIONS

I worked with the team to develop the healthcare sector revenue & profit prediction model. Then, from working with the customer team turned that model in to two potential contract models. After that, I built in many customizations in to the model so that the team could play around with contact parameters and visualize the outcome.

INNOVATION

Several iterations of a financial model that did not exist before for the healthcare sales funnel. Experimented with two potential contracts. Experimented with simulation in deterministic and stochastic variables. Using an iterative model and simulator as a way to predict potential P&L (profits and loss statements) outcomes was the primary innovation.

IMPROVEMENT

Initial design of contract and baseline for profitability based on current costs.

BEST PRACTICES

Organizing all of the data sources in one centralized database is important, and making sure the links to updated data can be pulled as appropriate for future iterations. Since most of the team is not python proficient, it would be recommended to build out a front end user interface in future iterations.

OTHER APPLICATIONS

This could be expanded to many other programs and sales channels at the company to better predict revenue and internal costs in the future, and understand margins as a result. Furthermore it would help the team quantify the financial impact of new contracts or procurement prices more quickly and get on the same page with a succinct visualization.

Product design / development / engineering | Retail | Product design and testing | FEA

Enhanced Digital Capability through the use of Simulation in Footwear Product Creation

BUSINESS PROBLEM

Digital capabilities have been identified as a key growth opportunity for footwear companies. The goal is to increase speed to market by reducing the average product creation timeline, in large part through an end-to-end digital strategy. A Product Creation Center serves as a nexus of collaboration, creation, and education in footwear, and may be seeking to evolve its capabilities by investing in performance-focused digital tools. Specifically, this project investigated Finite Element Analysis (FEA) simulation programs and other design-aiding software as tools for improving design process flows while generating cost and time savings.

APPROACH

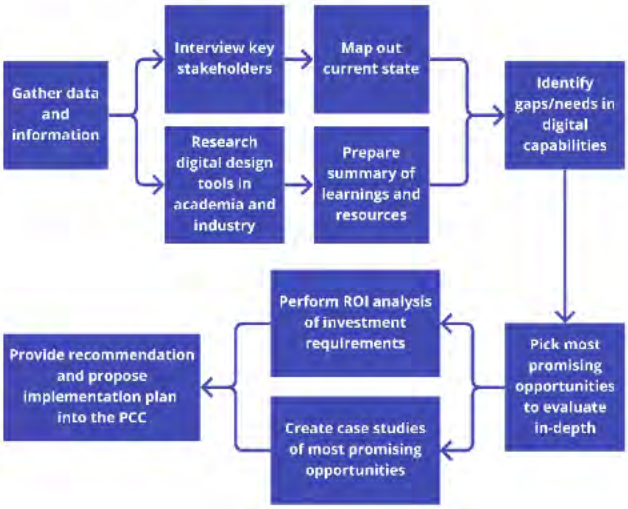
Information was gathered by interviewing key stakeholders and researching state-of-the-art simulation tools in product creation. Potential areas of analysis related to digital simulation capabilities were identified, and one example was detailed through a technical case study on the performance of soccer cleats. A cost-benefit analysis of the investment requirement for this example was developed.

DATA SOURCES

Information about digital capabilities was obtained through a state-of-the-art literature review, speaking with simulation experts, exploring existing internal knowledge through stakeholder interviews at the host site, observing internal processes, and shadowing work in a product creation center.

Data Types and Format

Qualitative data obtained through stakeholder interviews, CAD models, physical test data from 3D-printed models, and outputs from FEA software programs (stress, strain, and displacement data)



Author: Zoe Hinton

IMPACT

Enhanced digital capabilities have the potential to enable better decision making in the product development process at footwear companies. While there are no regulations or standards to be met as is usually the case in other industries that utilize tools like FEA, simulation is still valuable in footwear creation when comparing relative design features and models. One benefit of FEA is the potential to increase communication between designers, engineers, and manufacturing partners. Teams can test and iterate on multiple designs without making a physical sample while being able to visually communicate product behavior to designers. Design teams can have increased confidence in their products earlier in the design process as opposed to waiting for physical testing. FEA can also help save critical time and cost. FEA saves some cost by eliminating the machining of tooling needed for additional physical sampling rounds. But most importantly, teams can avoid waiting longer lead times to receive samples. Enhanced digital capabilities can also contribute to a company's sustainability goals by reducing materials and tooling used for physical sampling.

DRIVERS

Footwear companies must balance multi-year product development timelines and the risk with changing trends and attitudes of their consumers. It is therefore critical to shorten development timelines as much as possible. Digital simulation tools are commonplace in many industries, though it has previously been difficult to apply to the soft materials and geometries of footwear. Exploring how to implement digital tools is considered a top priority.

BARRIERS

Learning the appropriate FEA program to run simulations on footwear materials and geometries can take 6–12 months of training, which was out of the scope of the internship. It was a barrier to pick an appropriate technical case study that demonstrated this complexity that could be learned and performed quickly alongside a trained engineer. Coordination among engineering departments to get appropriate models and data was also vital.

ENABLERS

I had great support from multiple teams, as well as my manager. When I started, I was provided with a thorough deck outlining an organizational matrix and annual goals, as well as a list of important stakeholders to meet with among engineering and product teams. Later on, I was given priority to gather information from multiple teams, and even had support from business leaders to follow up with teams on my behalf.

ACTIONS

I began by immersing myself in all the teams I would be working with by performing one on one meetings to gather context and information from all levels, from designers and engineers to senior directors and VPs in product creation. From this I defined opportunity areas and gathered feedback. I down selected to one specific opportunity in order to provide a detailed technical and business analysis.

INNOVATION

On the technical side, I was able to demonstrate an example of a simple engineering analyses that could be used in place of full FEA simulations. On the business side, I developed a new take on a cost-benefit analysis that attempts to replace a quantitative return on investment analysis with something that addresses the qualitative factors that affect product creation and development.

IMPROVEMENT

My solution was able to map out the state of engineering analysis among multiple teams to provide transparency and sharing of knowledge. While FEA may not be best suited for a prototyping environment like a product creation center, I was able to demonstrate the advantages and benefit of the digital tool as well as outline different methodologies with varying levels of complexity to gather information for footwear designs decisions.

BEST PRACTICES

It is essential to get context surrounding current goals and practices as well as culture from the team level up to the department or company level. Final solutions should be tailored to the final audience, so having a solid understanding of a company's strategies, goals, and method of communication is invaluable.

OTHER APPLICATIONS

My solution only identified one use case for a specific performance metrics in sports footwear. This could be applied to different types of footwear or metrics. In addition, the process of going through a qualitative cost-benefit analysis can be applied to other investment decisions in the future, especially those that relate to digital tools in product development.

Operations | Transportation and logistics | Digital standard work / training | Tree-based

Performing Actionable Evaluations of Sustainability Investments

Amazon

BUSINESS PROBLEM

To meet their net-zero carbon goals, businesses are pursuing investments in emerging low-carbon technologies. Evaluating emerging technologies is difficult because their performance and cost are uncertain and standardized processes for evaluating their use have not been developed. In decentralized organizations, these problems are compounded by the variability introduced when different teams use different methods or assumptions to manage uncertainty. This project will investigate creating tools that transform investment evaluations from nebulous to actionable (high accuracy, high precision, address uncertainty).

APPROACH

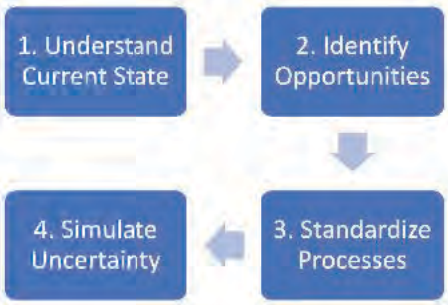
The project will work with decentralized finance teams to identify case studies and challenges to actionable investment evaluations. Tools (including a data repository, standard work document, and uncertainty analysis simulation) were built in an iterative process to address those challenges.

DATA SOURCES

There are 3 sources of data to be used in this project. One consists of Total Cost of Ownership (TCO) and Marginal Abatement Cost (MAC) evaluation spreadsheets from Amazon BUs. Another is data from industry for fuel price projections, battery cost, battery degradation, etc. The final one is data from Amazon BUs as they trial technologies.

Data Types and Format

Data come in various formats: TCO/MAC evaluations: Excel Industry forecasts: .csv, web Technology trials: .csv, Excel



Author: Jacob Hopkins

IMPACT

More actionable evaluations of sustainability investments will help companies move faster and save money as they achieve their sustainability goals. The standardized approach and shared central data provided by this project will reduce time spent sourcing data or performing internal forecasts. By providing a mechanism for data sharing between organizations and providing guidance for evaluations, companies will invest more consistently across their organizations - avoiding multiple trials for similar technologies, preventing poor investment decisions, and performing investments at the correct time. By providing a mechanism for data quality scoring, decentralized businesses will be able to independently evaluate their own data and project future performance as their understanding of technologies mature. By bringing all of this together in a simulation tool to address uncertainty, businesses will have a more complete picture of the possible outcomes of their investments and will be able to improve their decision making processes - achieving the goal of faster and cheaper progress to meet their sustainability goals.

DRIVERS

Amazon operates with a decentralized organizational structure. Business units (BUs) are empowered to make their own decisions. Worldwide Sustainability's (WWS) mission is to help BUs achieve the company's net zero carbon by 2040 commitment by providing tools, processes, and oversight.

BARRIERS

Amazon operates as a series of independent business units (BUs) that manage their own operations. This makes it challenging to standardize work across BUs. In addition, it is difficult to perform high quality evaluations because high confidence data is not readily available for the solutions they want to invest in.

ENABLERS

Amazon's embrace of custom developed tools enables a project like this to be successful. In addition, access to data-rich TCO models from multiple BUs allowed me to tailor my solution to address the challenges that BUs actually face.

ACTIONS

I tested various aspects of the project (data repository and standard guidance) with a limited number of transportation finance teams and iterated on them to satisfy user needs. The simulation tools were late breaking and were only presented in concept form as a potential solution.

INNOVATION

The innovative aspects of this solution are using Monte-Carlo analysis for Total Cost of Ownership (TCO)/ Marginal Abatement Cost (MAC) evaluations and implementing a method for independent evaluations of data quality. These components allow for more actionable TCO evaluations (e.g. by generating decision trees).

IMPROVEMENT

The tools I built will standardize more than 80% of a TCO/ MAC, and will enable detailed and rigorous sensitivity analysis using a Monte Carlo technique (up from none or simple worst-on-worst analysis before).

BEST PRACTICES

The process that I followed (understand the current state, identify areas of opportunity, standardize processes, and simulate remaining uncertainty) will enable others to implement a similar solution in other areas.

OTHER APPLICATIONS

Monte Carlo based sensitivity analysis can be applied to other sustainability investment categories beyond transportation and can also be applied to any evaluations of business cases.

Operations | Healthcare / Pharmaceuticals | Supply network connectivity / performance | Deterministic / Stochastic

External Network Manufacturing Capacity Design and Procurement in the Pharmaceutical Industry

AstraZeneca

BUSINESS PROBLEM

The pharmaceutical industry is experiencing significant market dynamic shifts caused primarily from the increased rate of innovation and the consolidation trends in the CMO space. Moreover, the increased occurrence of centralized procurement practices by the buyers have further deteriorated the API demand forecast accuracy. Thus, there is a need to develop new tools around external manufacturing capacity assessment and planning that allow the pharma company to instill responsiveness into the supply chain, bridging the flexibility gap between an external and a fully internal one.

APPROACH

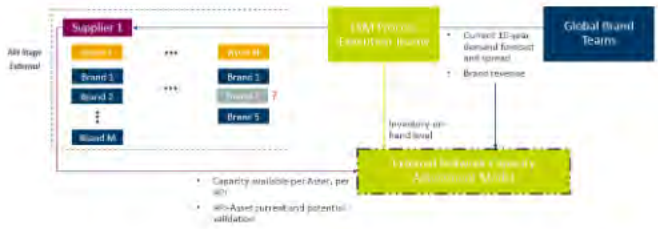
The shifting dynamics in the pharma company-CMO binomial begged for a 3-pronged approach to deepen the collaboration between the parties. The planning stakeholders were empowered with a capacity assessment model, which was further used to perform scenario planning to determine the optimal API-asset cross-validation configuration and to enhance the existing capacity reservation agreeements.

DATA SOURCES

1) 10-year API demand forecast data from the Global Brand Teams [kg] 2) actual API demand data from the downstream (formulation) stage [kg] 3) capacity available per asset from the CMO [days] 4) output rate per API per asset from the CMO [kg/day] 5) inventory design per API [kg] 6) inventory-on-hand per API [kg] 7) brand criticality measure from the Global Brand Teams [unitless]

Data Types and Format

The data is primarily in the form of time series in monthly and yearly increments.



Author: Ori Hoxha

IMPACT

IMPACT Given the 3-pronged approach that was followed in this work, the impact can also be traced across three avenues: First, the External Capacity Assessment Model (ECAM) provides a data-driven way to determine where capacity constraints might exist in a portfolio and what supply shortfall risks the pharma company is due to encounter over the next 10 years. The proposed ways of working allow the company to reduce waste, i.e. time and resources, in the strategic capacity review process. Second, the easy-to-modify nature of ECAM allows the planning stakeholders to perform API-asset cross-validation configuration scenario planning, such that alternative ways to relieve capacity constraints can be easily identified. This capability, when exercised openly with the CMO stakeholders, allows for increased transparency and trust-building in the capacity constraint mitigation process. Moreover, the quantitative outcomes observed through the Monte Carlo analyses based on the ECAM algorithm, inform what degree of manufacturing flexibility would alleviate any remaining demand downside and upside risks. Third, the manufacturing flexibility analysis was applied on a per asset basis to inform the design of an alternative option contract-driven capacity reservation model. The proposed agreement between the pharma company and the CMO allows for the former to increase its service level at constant COGS, while allowing the latter to increase its 10-year returns by up to 50%.

DRIVERS	The mutual understanding across the pharma company and the CMO stakeholders that the new operating model needs to be better than the status quo at "consistently sharing the gains and the pains" between them. Moreover, given the stochastic nature of the API demand, there was a drive to identify tools that simultaneously hedge against both demand downside and upside.
BARRIERS	The navigation toward a new local optimum where the pharma company and the CMO are more transparent to one another about their cost structures, priorities and other manufacturing-floor constraints, brought about confidentiality challenges that required to find the right balance between a specific-enough understanding of the factors at play and an abstracted view.
ENABLERS	The recent reorganization of the internship host department allowed for increased access to ongoing and rekindled conversations around the pharma company-CMO operating model. Also, the long-term relationship between the pharma company and the proof-of-concept CMO also accelerated the attitude shift toward an increased degree of information-sharing.
ACTIONS	1) interviewed 20+ pharma company internal stakeholders across departments, i.e. External Supply & Manufacturing, Procurement, Global Supply Chain etc. 2) interviewed 3 external stakeholders from the proof-of-concept CMO, and participated in 2 inter-company workshops on the evolution of the operating model 3) utilized a continuous feedback loop with the primary internal stakeholders to validate the feedback synthesized and the tools developed
INNOVATION	1) Intertwining the concept of "chaining" and "pooling" in a small-molecule manufacturing set-up, in order to understand their benefits and limitations across varying demand correlation and volatility 2) Exploring "option contracts" as a way to reserve manufacturing capacity at a CMO on a per asset basis, and allow the pharma company to hedge against both demand downside and upside
IMPROVEMENT	1) Automatization & standardization of capacity assessment at an CMO-aligned portfolio, brand and asset level 2) 6% reduction in supply shortfall, while limiting the risk to the lowest brand criticality product in the portfolio through optimized API-asset cross-validation design 3) Increased pharma company service level at constant COGS, while increasing the CMO 10-year return by 50% through an option contract-driven capacity reservation model
BEST PRACTICES	1) Decentralize the capacity assessment process and allow relevant stakeholders to input data into the model independently 2) Regular workshops with the CMO stakeholders to review the option contract design in terms of cost structure and the relevance of the assets included in it
OTHER APPLICATIONS	1) Extensions into and adaptations toward other technology areas, i.e. medical devices, gene therapies, oligonucleotide therapies 2) Empowering the manufacturing flexibility target through forward-looking Machine Learning demand forecasting algorithms

Production | Metals and mining | Performance management | Constrained / Unconstrained

Improving Throughput in an Aluminum Rolling Mill

AMERICAN INDUSTRIAL PARTNERS

BUSINESS PROBLEM

Commonwealth Rolled Products (CRP) manufactures aluminum rolled products to supply the industrial and automotive sectors. CRP aims to increase their customer volumes significantly over the next three years and needs to understand how different operational events and product mix impact annual throughput. The objective of the internship program with CRP is to provide a quantitative analysis on the current state and future state throughput of the complex continuous line (CCL).

APPROACH

The analysis includes a heuristic model to determine the throughput and identify key performance indicators (KPIs) that impact throughput improvement the greatest. This model will recommend a roadmap to achieve a sustainable operations plan and sales forecast that will enable increased manufacturing capacity.

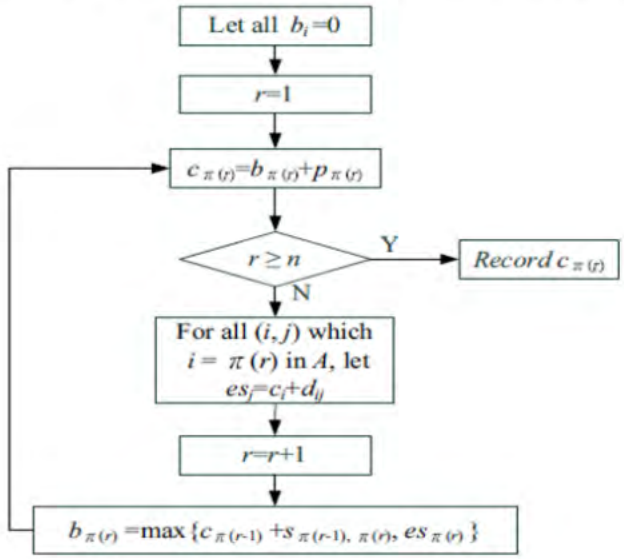
DATA SOURCES

Data was collected through a variety of different method, but the primary operational data source originated from the CCLs' propriety software and data storage system. The data was stored in an oracle database which allowed for easy SQL extraction and Python and Excel manipulation.

Data Types and Format

Time series, tabular, visual inspections, discussions with subject-matter experts.

Mixed Integer Program – Optimization Makespan Calculation



Author: Scott Hungerford

IMPACT

The CCL heuristic model led to a 4-year operational and throughput roadmap that CRP is using for their Sales, Inventory, and Operations Planning (SIOP). The model set goals for quality, recovery, and line speed increases. These goals also led to CRP establishing unique improvement projects for each identified KPI since they were deemed to be impactful to throughput. When comparing the heuristic model to historic performance, the model was within 5% of the processed metal weight and 10% of total transition coils for a given month. Since the transition coil estimate was not as precise as the author desired, a mixed integer program was developed to determine if a different approach could predict transition coils more accurately.

DRIVERS

The existing trend to manufacture products out of aluminum instead of traditional steel products. Increased American production will create additional aluminum demand given the lighter weight of aluminum and improved metallurgical properties.

BARRIERS

The major challenges to develop this model was the lack of domain knowledge and extracting useful information from the available data. It took time to understand the entire rolling process and to narrow down the unique manufacturing capabilities of both the plant and the CCLs. Understanding which data sources were useful in the analysis was difficult because it was challenging to differentiate specific process that should be included in the study

ENABLERS

Both the subject matter experts and management team supported this project and provided the necessary time and resources to enable success. Feedback was continuous and the CRP team was open to teaching me the necessary information to develop this project.

ACTIONS

Subject matter experts were key stakeholders in the project and their expertise enabled the model to perform as intended. We presented the model and findings to management and received feedback and approval of the strategy and recommendations.

INNOVATION

In addition to the heuristic model, the mixed integer program was a unique approach to aluminum rolling. The MIP model seeks to find the optimal job sequence to reduce transition coils and ultimately minimize the makespan.

IMPROVEMENT

The heuristic model led to a 4-year operational and throughput roadmap that CRP is using for their Sales, Inventory, and Operations Planning (SIOP). However, the mixed integer program calculated a 60% decrease in product changeovers when coupled with monthly batching and advanced scheduling techniques. The MIP derived schedule has not been tested in real time operations.

BEST PRACTICES

Get the technical team involved early in the project planning stages. I could have been more efficient with my time had I asked the right questions to the correct people.

OTHER APPLICATIONS

The MIP optimization program could be applied to any single machine operation where product changeovers impact the overall throughput.

R&D | Healthcare / Pharmaceuticals | Defect detection / product inspection | Supervised Learning

Developing a Data-Driven Strategy for In-Process Quality Assurance for Additive Manufacturing

stryker

BUSINESS PROBLEM

Stryker has seen high growth in additive manufacturing as it enables more complex designs that yield better patient outcomes. However, additive in the medical space requires important and labor-intensive testing to ensure every product is safe for use. Testing takes place after parts are finished, days after the build starts, creating a pool of WIP inventory. Problems that are identified may render parts that have been built on the same machine since as scrap. Stryker seeks to build a strategy for the high volume of data generated during the build process to develop in-process quality checks and in-process feedback before testing occurs.

APPROACH

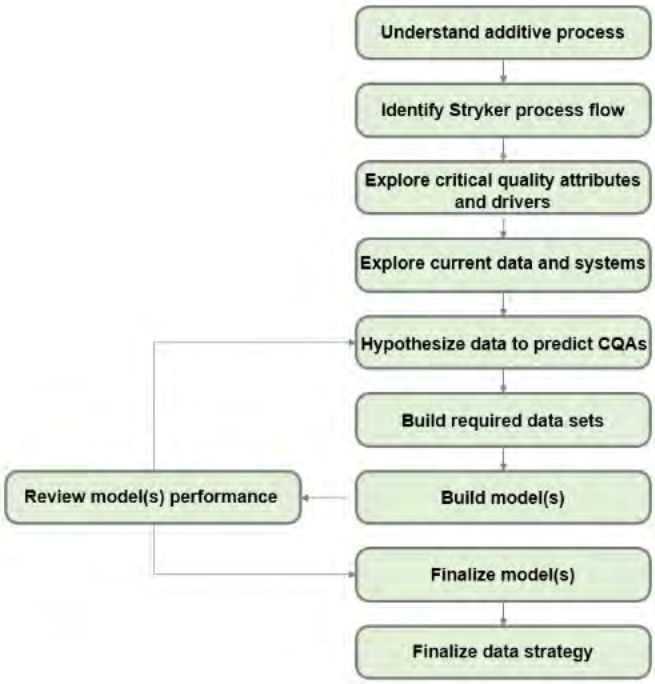
First, understand the key critical quality attributes required for a part to pass quality checks. Then, explore the factors that drive those attributes and use data to explore the relationships between them. Finally, identify data significant for predicting quality attributes or gaps in current data.

DATA SOURCES

Environmental data from additive machines (sensor-based), build attributes (software-generated), input material data, post-processing data

Data Types and Format

time-series data and categorical data



Author: Mariam Ibrahim

IMPACT

In-process QA will allow Stryker to generate less scrap, ultimately reducing the amount of raw material needed. Removal of some testing equipment will act as an increase in capacity as additional floor space is freed, allowing for additional additive manufacturing machines.

DRIVERS	Enabling less variation in daily operations as well as an increase in effectively capacity
BARRIERS	Working across multiple data systems/lack of centralization, data stored across a variety of formats
ENABLERS	Clear ownership of areas of operations, clear scope
ACTIONS	Key actions included meeting with team members across Stryker's additive operations to leverage area expertise, incorporating feedback early, and building relationships
INNOVATION	Leveraging data and data science for prediction of manufacturing outcomes
IMPROVEMENT	Using a data science solution will enable reduction in quality testing volumes and improve throughput
BEST PRACTICES	Spend significant time talking to data and process owners, who can explain nuances of different trends. Ask individuals who work on the floor what happened on specific days where data clearly differentiates from average. Discuss thought processes with experts, and return to underlying science (thermodynamics, fluid mechanics) when considering results
OTHER APPLICATIONS	Other applications include quality assurance across different manufacturing processes outside of additive

Operations | Metals and mining | Improved process performance | Linear / Non-Linear

Optimization of Process Furnace Emission Reduction Investments for Private Equity Firms

AMERICAN INDUSTRIAL PARTNERS

BUSINESS PROBLEM

PE shops that acquire industrial businesses have a difficult environmental challenge because their investments are more emissions-intensive due to the complex supply chains and energy-intensive operations. The lack of universally adopted tools that connect investment decisions and emissions reductions with value creation leads to a lack of conviction for management to take action on climate change, and insufficient deployment of private capital towards global decarbonization. This research focuses on emissions reduction for manufacturing lines, because successful operation of those lines is critical for company profitability.

APPROACH

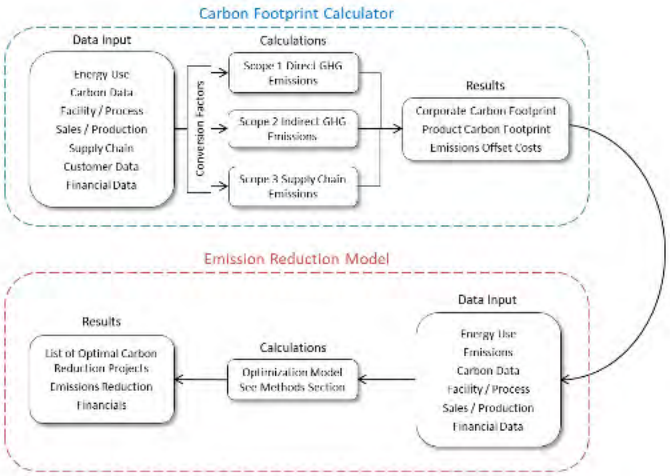
We contribute an integer linear program that finds the most profitable strategy to reduce CO2 emissions from process furnaces by scheduling furnace upgrades each year within the planning horizon. The model is based on certain emission reduction technologies, fuel and carbon pricing, and process characteristics, and the results are constrained by financial parameters.

DATA SOURCES

This research used process data collected across multiple manufacturing stages and from all plants across the globe. We also used electricity and gas data from meters and utility bills. We used financial data from historical projects, when available, or estimates, when needed.

Data Types and Format

Majority of process data is time-series, or cumulative annual data. Process data was well structured.



Author: Peter Emanuel Jacobson

IMPACT

The emissions models helped the organization identify the scope of their challenge and set of relevant of solutions, plus gave teams a platform to confidently discuss capital allocation and operational decision-making for emission reduction. The host company can profitably meet their 2030 science-based emissions reduction target if there is carbon pricing. That scenario includes 50% cleaner electricity supply through a power purchase agreement. Our research also shows that ignoring the effect of process improvements on manufacturing equipment upgrades greatly undervalues the financial performance of decarbonization initiatives. A main driver for cost savings came from process benefits such as scale reduction and throughput improvement. Accounting for process benefits from furnace upgrades improved cumulative savings through 2030 by 100%.

DRIVERS	The industry faces pressure to reduce emissions, but is not confident that investing in emissions reductions is complimentary to maximizing returns for investors.
BARRIERS	Data availability on benefits of certain emissions reduction projects. Limited budgets and competitive selection process to invest in new projects.
ENABLERS	Strong support from the partner company across many functional roles. Robust history of data collection and KPI tracking.
ACTIONS	Interviews and ongoing engagement across different functional teams to encourage ownership, increase contribution, and build support. Presentations to executive team to secure the investment needed to implement the solutions.
INNOVATION	The use of an optimization model to schedule emissions reduction investments while minimizing costs to the business.
IMPROVEMENT	5-35% reduction in furnace emissions, depending on final implementation of projects.
BEST PRACTICES	Developing relationships with the manufacturing and operations teams ensures you have an accurate source of information and team buy-in, and developing relationships with the executive team ensures you will have support to invest resources into the identified solutions.
OTHER APPLICATIONS	This approach is broadly applicable to any process lines where data is available on energy usage, yield, and process costs.

Supply chain planning and inventory management | Healthcare / Pharmaceuticals | Supply network connectivity / performance | Network analysis

Digital Supply Chain Connectivity and Capacity Analysis for Strategic Production Planning

BUSINESS PROBLEM

Ethicon, a subsidiary of J&J that designs, manufactures and distributes medical devices used by surgeons around the world to conduct surgery safely and effectively, is experiencing increased demand within its Oxidized Regenerative Cellulose (ORC) product line. Data related to the ORC production value stream is generated across both internal and external suppliers within J&J's global supply chain; as a result, the digital data thread is disjointed across multiple ERP systems and various teams. Consequently, planning activities that support strategic investment decisions are increasingly burdensome and require a significant level of effort.

APPROACH

A process flow analysis of the ORC finished goods facility will be performed to develop a dynamic capacity model that supports identification of critical bottlenecks for strategic investment opportunities and improvements. Furthermore, a characterization of the ERP systems across J&J's supply chain will be used to roadmap a plan for connecting the information flow throughout the value stream.

DATA SOURCES

This research primarily used data from various teams within the ORC value stream. Demand information, planning sheets, and forecasts were aggregated across these various teams. Additionally, process and manufacturing data were gathered from various MES/ERP systems used by Ethicon in ORC production.

Data Types and Format

Planning, demand, and forecast data in shared Excel spreadsheets. Manufacturing and process data from various MES/ERP systems.

Author: Justin Jiang

IMPACT

Successful implementation allows Ethicon's ORC product line team to effectively and efficiently manage its finished goods facility throughout its planning cycles as well as identify and execute on strategic investment opportunities for future demand profiles.

DRIVERS

A major driver of this project was the growth in ORC product demand and the need to understand and identify tactical and strategic operational improvements in the ORC value stream to meet that demand.

BARRIERS

Availability and access to some subject matter experts and data sources due to production schedule focus. Size of scope (raw materials node, finished goods node, digital strategy) and limited time detracted from depth in any particular area.

ENABLERS

The strong support from the leadership team and the company culture enabled the results of this project. The site visits were also instrumental in understanding the dynamics of the manufacturing process and gathering valuable information from the operators.

ACTIONS

Accessed educational resources within Ethicon to understand the ORC product line and history. Met with subject matter experts across the organization (enabled by the site visits) to become familiar with ORC production. Feedback from leadership teams on what visualizations would be beneficial to the teams.

INNOVATION

The use of digital tools (PowerBI) to automate data capture and aggregation. This up-to-date data aggregation is then used by the optimization algorithm to suggest an optimal product mix to maximize revenue (and minimize shortfall) given product demand profiles and current manufacturing capacity constraints.

IMPROVEMENT

Capacity models that provide dynamic updates on capacity utilization at different process steps based on tunable input parameters (demand, product mix, operational efficiency, etc). Optimized product mix that provided a minimized revenue shortfall of 0.5% on simulated demand and capacity constraints.

BEST PRACTICES

Build relationships with the manufacturing leadership all the way to the operators as they are the closest to the product and have highest fidelity data for how the product is made.

OTHER APPLICATIONS

This approach can be applied to other product value streams within the Ethicon and greater J&J product portfolio.

Production engineering | Aerospace and defense | Improved process performance | Deterministic / Stochastic

Parametric Study of Environmental Testing in Satellite Manufacturing

Amazon

BUSINESS PROBLEM

As Amazon Project Kuiper transitions to full-scale production in its satellite factory, the manufacturing team needs to estimate the proper amount of environmental testing equipment. The machines are expensive and take a lot of space on the shop floor. However, there is little data for the suspected failure rates of the different components in the satellite resulting in uncertainty around throughput. The research tries to solve the estimation of the number of environmental test machines that will be required for a new production process.

APPROACH

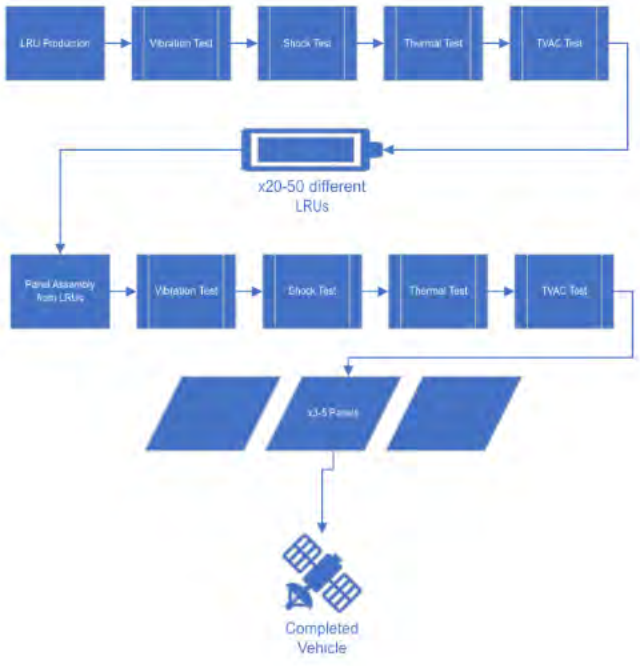
I created a deterministic model to calculate the number of machines that are required at a factory level. This model aims to predict testing requirements at all of the different time periods that the factory will experience in its first three years of production. These outputs can be used to appropriately plan for the large expenses required from these machines.

DATA SOURCES

The model uses inputs for each main test: Vibration, Shock, Thermal, and TVAC. Data for each of these tests were collected through experimentation and published standards in accordance with SMC-S-016. This data includes specific temperatures and times that are needed to conduct a test.

Data Types and Format

These includes times, temperatures, and costs for each of the machines. These were all collected in comma-separated-value (CSV) format and analyzed using Microsoft Excel.



Author: Mitch Johnson

IMPACT

Low Earth Orbit Satellite constellations have begun to provide consumers with internet access in remote and under-served areas. Firms have begun to manufacture satellites at a higher rate than ever seen before in the aerospace industry. These satellites require environmental qualification testing to meet the standards required to launch and operate in space. For a new product, it is unclear how much testing capability will be necessary. This research provides an in-depth look at efforts to estimate the correct capital expenditure for the purposes of environmental testing for satellite manufacturing. It uses uncertainty analysis and parametric studies to compare options for precision manufacturing in an unknown field of production. The study finds that testing machine requirements vary through different periods of production, challenging the producer to purchase more capacity than will ultimately be necessary. These results highlight the need to develop failure rate predictions at the lowest component level to accurately assess testing requirements for the overall system.

DRIVERS

A major driver for the project was the need to conduct critical path analysis and understand that testing was a key capacity limitation in the overall system. This led to the effort to identify current capacity constraints and model projected demand from the production system.

BARRIERS

The largest barriers were assumptions that had to be made for yield rates, rework times, and projected build rate. There was little information for some of the key inputs to the model and assumptions had to be made to produce meaningful results.

ENABLERS

This project was enabled by a strong team at the company and enabled by a willingness to creatively problem solve. The company's open structure allowed for collaboration across different departments to come to a working model for this problem.

ACTIONS

Interview and speak with numerous experts across the company to come up with an approach that helped to solve this problem. I also simplified the problem when possible to get results that could then be iterated when more data became available.

INNOVATION

The use of a model to predict the test machine capacity and collaboration amongst many different teams of component engineers to compile the data and information in one model.

IMPROVEMENT

The final solution provides a range of scenarios that the company must consider in the environmental test machine purchase decision. Each scenario provides a specific number of machines that will be necessary in order to meet demand from scheduled launches.

BEST PRACTICES

Develop a strong relationship with the testing team and manufacturing engineers while networking across as many sub-component teams as possible. Understanding each individual team's perspective can help make the model more practical and useful to the entire production team if input from the lowest level is included.

OTHER APPLICATIONS

This research could apply to any production process where large capital expenditures are required and there is uncertainty around the performance characteristics of the product. Unknown failure rates drive the need to create a model to better predict outcomes and advise decision makers with the most accurate information.

R&D | Healthcare / Pharmaceuticals | Improved process performance | Network analysis

Enhancing Workflows in Biologics Drug Substance Process Development Through Automation

BUSINESS PROBLEM

Historically Amgen's pipeline has been dominated by monoclonal antibodies (mAbs), enabling use of "platform" production processes that are relatively invariant between products & efficient to develop. As molecules more unique & complex than mAbs become the norm, platform processes cannot be relied upon. Instead, unique off-platform processes must be developed, currently demanding much more time & resources. Well-implemented automation may increase development speed & flexibility to overcome these hurdles, but where & how are not yet clear. Existing automation tools are often siloed, inefficiently applied, aging, and insufficiently supported.

APPROACH

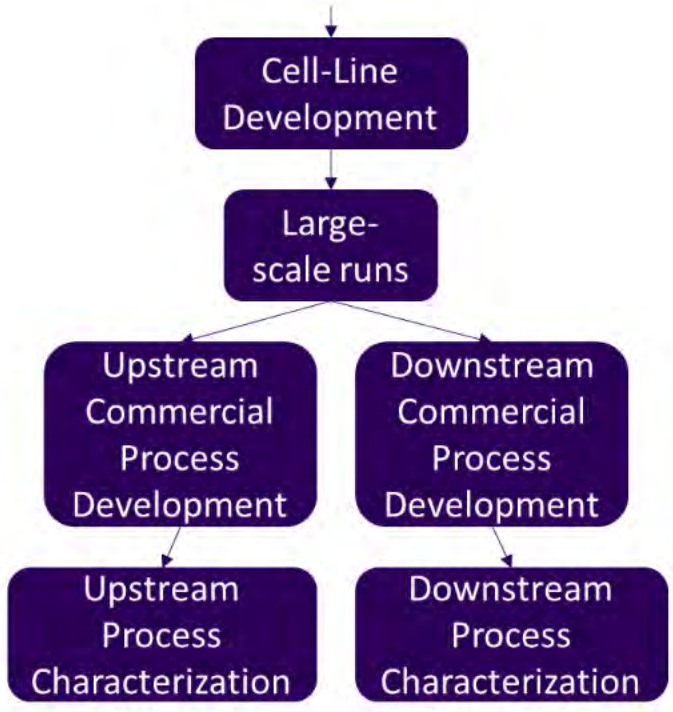
A process map of biologics drug substance process development in its current state, from cell line development through process characterization, was created. Criteria for determining valuable opportunities for automation were defined and applied to different stages of the development process to identify a leading opportunity. The direct NPV and indirect benefits of this change were then assessed.

DATA SOURCES

Data was sourced through interviews with functional SMEs. Timelines (in Gantt charts) of current process development projects were also. Resource model spreadsheets detailing the resources assigned at each project stage were used to assess FTE demands at each project stage. Academic literature was explored to establish a benchmark for automation use at competitor firms.

Data Types and Format

Data collected in interviews was organized visually in construction of a process map and compiled into an excel spreadsheet for analysis. Resource model data is already in structured spreadsheet form.



Author: Alexander LC Judge

IMPACT

Through cross-industry benchmarking and analysis of the process map with an eye towards the impact of automation tools & uses on KPIs such as the number of FTEs required and the speed of project completion, automation tools and uses can be assessed and prioritized based on their cost of adoption and expected impact on these KPIs. Drug Substance process development efforts are on the critical path for bringing a product to market. Reducing the time required for process development would help Amgen beat competitors to market in indications where many firms are developing similar products, allowing Amgen to benefit from the substantial first-to-market advantage in the industry and to bring new medicines to patients more quickly. By reducing the number of FTEs required for a project, Amgen can also take on a greater number of projects at a lower cost per project, allowing increased diversification of Amgen's pipeline, a key factor in ensuring the long-term success of the company given the high-risk nature of each individual project. By reducing the costs of process development, Amgen reduces the expected losses from investing in process development efforts "at-risk" while clinical success is still uncertain, making it more attractive to begin these critical-path activities earlier at-risk and further improving Amgen's speed to market and accompanying competitive advantage. The methodology used can also be applied to assess automation needs & value in other firms & industries.

DRIVERS

Drug process development is complex by nature, requiring deep technical specialization in many functions. Biopharma firms must also be very large in order finance the high cost of development & commercialization for the many pipeline products necessary for sufficient diversification of these high risk investments. This combination leads to highly siloed structures such that cross-functional analysis can provide rare & valuable insights.

BARRIERS

A significant barrier to completion of the project was developing the level of understanding of each stage of biologics process development necessary to think about the space holistically, analyze the processes appropriately, and make well-informed recommendations.

ENABLERS

Amgen employees across the board have been very eager to help and have been very informative. Amgen also strives to keep very thorough data on the timelines and progress of past and current projects.

ACTIONS

In the first stage of the project, I had conversations with many leaders and technical experts in the biologics process development space to gain a thorough understanding of the workflows, tools, timelines, and resource requirements of each stage from cell line development through process characterization. Using the information gathered in these conversations, a process map will be constructed and analyzed for automation opportunities.

INNOVATION

The most innovative aspect of the solution was building out a framework for assessing the impact of staffing support model on the value that can be derived from the implementation of automation tools.

IMPROVEMENT

The solution provided substantial reduction of the time and resources required for biologics drug substance process development. The NPV is likely to be positive, but the magnitude of this depends on the ultimate lifetime of the equipment and capacity utilization that can be achieved. Supporting the equipment with an appropriate staffing model will help ensure the potential improvements are realized.

BEST PRACTICES

Start by building a thorough process map. Then look for the stages of the process with the characteristics of a process that can benefit strongly from the implementation of automation: repeated tasks, parallelizable tasks, and low value-add work done by high-skill employees. After promising areas have been identified, quantify the value (both direct an indirect) that can be provided by automation and consider what staffing support model is best.

OTHER APPLICATIONS

The methodology used to assess the needs and value of automation can be applied to other firms and industries where the demands on the process are changing over time. For example, it may be used for the formulation development process in plant-based food firms rapidly expanding their product portfolio after early success with a single flagship product.

R&D | Transportation and logistics | Customer service / connectivity | Linear / Non-Linear

Evaluating the use of hydrogen fuel vs. electrification for medium- and heavy-duty transportation

nationalgrid

BUSINESS PROBLEM

As organizations look to decarbonize transportation, two main technologies arise: electric vehicles (EVs) and hydrogen fuel-cell batteries. EVs already dominate the light vehicle market and have infrastructure in place, but aren't always well suited for heavier, longer-range vehicles in the medium- and heavy-duty transportation sector. Hydrogen fuel presents a decarbonization solution that meets many of the needs of MD/HD transportation, but production, infrastructure, regulation, safety, and supply factors must be evaluated across the value chain. This project evaluates the use of H2 or EVs for major MD/HD transportation applications.

APPROACH

This project uses a framework that evaluates critical criteria for each technology (EV vs. H2). These criteria include: total cost of ownership, infrastructure capacity, subsidies, external / social costs to society, safety, and other risks. The following major MD/HD sub-sectors applications are evaluated: Long Haul, Short Haul, Parcel Delivery, Tipper, Refuse, School Bus, Transit Bus & Forklifts.

DATA SOURCES

National Grid internal LCOE modeling for Hydrogen (LCOH). Historical and burgeoning regulatory subsidies currently used and being pursued by NG and other major industry players. Locations of proposed hydrogen hubs. Cost modeling projections from the DOE, National Labs (ANL and NREL), and other academic peer-reviewed journals. National Lab vehicle drive cycle modeling (NREL's FastSIM).

Data Types and Format

Excel, CSV data fiels

Evaluation Criteria		MD / HD Fleets Evaluated							
		Long-Haul	Short-Haul	Parcel Delivery	Tipper	Refuse	School Bus	Transit Bus	Forklifts
Total Cost of Ownership Analysis	CAPEX Costs (Purchase Price, Salvage Value)								
	OPEX Costs (Fuel, O&M, Infrastructure Fees, Payload, Driver Salaries, etc.)								
	Incentives and Subsidies								
Infrastructure Capacity	Current State								
	Future / Projected State								
Social / External Costs	GHG Emissions								
	Mining Rare Earth Metals								
	Noise Pollution								
	Air Pollution								
	National Security								
Risks	Financial Risks								
	Technical Feasibility Risks								
	Safety Risks								

Author: Lindsey Kennington

IMPACT

A detailed recommendation is crafted to determine which MD/HD markets should be pursued. This recommendation considers the criteria outlined in the "Approach" section above (vehicle total cost of ownership, infrastructure capacity, subsidies, external / social costs to society, safety, and other risks). This study enables National Grid to seek out and build value-added strategic partnerships with potential hydrogen end-users in the MD/HD transportation sector. National Grid is a key player in the newly proposed Northeastern Hydrogen Hub (H2Hub), and the success of this H2Hub hinges on the collaboration and support from key stakeholders and end-users - MD/HD fleets, in this case. A data-backed mechanism that illuminates which MD/HD transportation fleets should consider Hydrogen fuel-cells and which should consider electrification is a strategic advantage that will enable National Grid to make the most effective strategic partnerships and add more value to their existing and future customer base. This study determined that long-haul trucking fleets (750-, 500-, & 300-mile range) that operate until multi-shift and weight-limited operations are the most natural entry point into the MD/HD fleet market, given the current costs across the vehicle value chain. That said, because long-haul hydrogen fueling infrastructure is insufficient in the US outside of California, working with these fleets now to develop that critical infrastructure (as a part of developing H2Hubs) is critical.

DRIVERS

The main catalysts of this project are recent opportunities to secure funding and develop H2 projects. These new, clean energy development opportunities are a result of the recent IIJA and Inflation Reduction Acts. Several electrification and H2 projects have stemmed from this legislation; the most relevant development projects to this research are the Regional H2 hubs. The success of these hubs will depend on what end users exist.

BARRIERS

A major barrier to the project are the risks associated with using H2 as a fuel because the technology and MD/HD transportation uses are relatively new/untested and represent large uncertainties at scale. This analysis includes a risk analysis to account for various uncertainties and known hazards related to the future hydrogen economy and is evaluated through three main risk categories: financial, technical, and safety.

ENABLERS

National Grid's involvement as a regional H2 Hub strategic partner has enabled NG leadership to prioritize research around a deeper understanding of decarbonization pathways for MD/HD transportation. Significant research and planning in this area allows National Grid to make informed decisions and forecasts as a stakeholder in the Northeastern H2 hub.

ACTIONS

Analysis using the framework provided on the first page will be performed to generate a decision roadmap for H2 and/or electrification MD/HD project development.

INNOVATION

This project will incorporate innovation in three major areas. First, technical innovation - this project will be evaluating cutting-edge H2 technology for incorporation on a commercial and public scale. Second, regulatory innovation - the success of H2 largely hinges on what new regulatory incentives exist and can be leveraged to make H2 viable from a cost and development perspective.

IMPROVEMENT

This study and accompanying thesis provides a quantifiable analysis on future markets that National Grid (and other stakeholders in US Hydrogen Hubs) can use to determine how best to allocate capital and other resources to support future business development and gain a strategic advantage in the industry.

BEST PRACTICES

A recommendation for future work in this area would be to leverage the resources and work done by the DOE and National Labs. Time and resources are much better spent refining and adding to the existing body of research rather than reinventing the wheel.

OTHER APPLICATIONS

Future work should expand to more niche markets that have a higher level of cost uncertainty, such as heavy-duty mining vehicles or other specialized heavy-duty construction equipment. These vehicles have limited cost data available, as no FCEVs are currently operating on the market - but could be a natural fit for hydrogen fuel as on-site production would likely be an option and the EV battery size could be cost-prohibitive.

Operations | Telecom | Customer service / connectivity | Unsupervised Learning

Applying Satellite Broadband Connectivity with Edge Computing to New Industry Verticals

BUSINESS PROBLEM

Kuiper has the potential to deliver high-speed internet to many areas around the world that are not adequately served by existing fiber or geostationary satellite solutions. This project is focused on new industry verticals where Kuiper can open up market segments of non-consumption of internet services in areas where this may not be affordable at cost but which could create a market pull for other services. In particular, the project identifies a specific target segment and a "beachhead" customer for the launch of the concept.

APPROACH

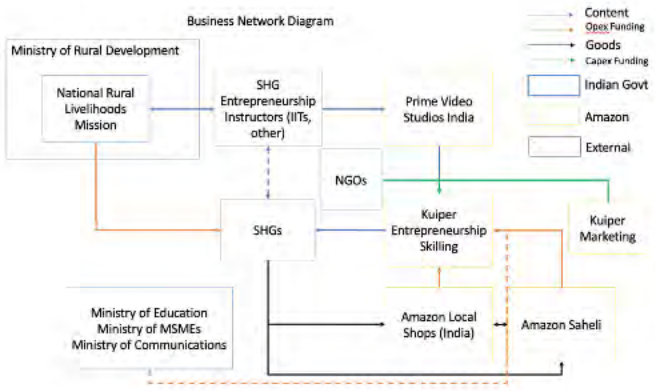
Because the scope of the problem is very large, I considered what types of market segments existed where high-speed, low-latency internet service would add some type of benefit and help create a "pull" demand for this and other services. I narrowed the focus to a particular use case of high-speed internet in a remote area for a specific country, with a view to future applications elsewhere.

DATA SOURCES

Current data available include high-level population statistics regarding literacy, internet access, internet usage, income levels and occupation for large regions of India. These data have been sourced by consulting a professor at IIT Bombay and from the sources of Akshit Singla's SDM thesis on the "Digital Divide", as well as Detecon Consulting on the topic.

Data Types and Format

Processed population-level statistics, as well as some video job-skilling examples from Devdip Purkayastha's nonprofit Enactus.



Author: Scarlett Koller

IMPACT

The proposed solution is a Kuiper-enabled connectivity station for education & job-skilling use in villages in rural India. This was selected as a use case to enable access to the internet with "pull" content in areas where many are unable to access internet services. This solution may open up new customers and market segments for Kuiper internet services in both the current project focus but also in other segments if the project succeeds in creating a "pull" for other services. If successful, it would likely give Kuiper a broader foothold in certain markets outside of those that would be typical targets for an internet service with this cost structure. Additionally, the selection of India as an initial region to focus on is intended to support Amazon's case to provide Kuiper services in India. India represents an enormous share of Kuiper's possible customers, but the regulatory framework can be challenging, and competition from 5G mobile providers is set to be fierce. With a Kuiper product aimed at a social benefit such as increased education and opportunities for adults in rural areas, Amazon hopes to engender government goodwill to aid in navigating the regulatory framework. The station design is intended to be installed at either a local "kirana" shop or in a communal village area, allowing use both by adults in rural "Self-Help Groups" for entrepreneurship skilling and for other entertainment or study purposes.

DRIVERS

Kuiper Business Development was looking for a way to create a pull for satellite internet in market segments of non-consumption. In order to narrow the scope of this project, I focused on the large population of India and a specific use case of adult learning & job-skilling. This was a natural choice as it would also leverage synergies with Prime Video. Rural Self-Help Groups posed an ideal beachhead use case for this type of content.

BARRIERS

Currently, major barriers include a difficult regulatory environment in India where telecommunication authorities have strict requirements. Additionally, it is difficult to fully understand the scope of possible solutions from outside the country. However, this project's possible social benefits can engender goodwill with the regulatory bodies. Difficulties in honing the solution can be overcome with pilot programs in specific villages.

ENABLERS

This project is enabled by the greater Amazon "flywheel" that encourages synergies between different business units. This project leverages existing development of Kuiper Customer Terminals, Prime Video studios in India, and Amazon Saheli and Local Shops on Amazon.in. Product Managers across Kuiper Business Development showed support for the project concept once opportunities across multiple divisions were shown.

ACTIONS

Current actions include connecting with job-skilling and educational efforts that already exist in some of the target regions of India, developing a high-level concept design involving existing Amazon hardware solutions, deriving both technical improvements and process workarounds for monsoon loss of signal and writing documents to ensure this project continues with Amazon beyond the internship.

INNOVATION

The concept will combine content intended to pull users to the platform to go beyond the mere provision of connectivity and create a business case for fixed broadband in order to compete with 5G mobile providers. The solution also includes a dedicated Kuiper ground station design which comprises a power system with solar arrays to reduce dependency on local infrastructure and incentivizes uptake in underresourced areas.

IMPROVEMENT

If implemented at scale, the project could help scale existing job-skilling efforts (such as "Tech for Tribals" from IIT Kanpur and other entrepreneurial skilling for rural Self-Help Groups) using satellite internet connectivity and equip millions of underserved adults with tools to build small businesses. This will also bring new sellers to Amazon's Local Shops and Saheli platforms as well as encouraging paid use of Kuiper internet.

BEST PRACTICES

If attempting to replicate this approach, it is imperative that others consider carefully the specific needs of the underserved, underconnected market segment they aim to address. Supplying internet connectivity does not add value unless there is a pull by local users to access it and apply it to their lives. This is why a specific beachhead use case was considered and follow-on use cases analyzed for their revenue-generating ability.

OTHER APPLICATIONS

This type of solution could be applied to multiple use cases, including possible expansions of electronic banking access and even telemedicine communications.

Product design / development / engineering | Aerospace and defense | Product design and testing | Unsupervised Learning

Outside Inside, Inside Around: Leveraging External Innovation Through Strategic Investment

BUSINESS PROBLEM

Boeing has over a century of experience developing and manufacturing quality aviation and aerospace products. Through refined processes, they build and implement complex systems globally. Because continuous improvement and company growth are fundamental for future business success, companies constantly look for ways to innovate. A large company must operate to augment core business and create industry innovation to succeed. However, decades of literature and company performance reviews have demonstrated that large companies often struggle to develop innovative products or to foresee disruptive technology to capture the market quickly.

APPROACH

By exploring the confluence of Boeing technology gaps, opportunities to augment existing Boeing Core Businesses, and the utilization of Portfolio Company (PortCo) expertise, the Boeing Corperate Venture Capital (CVC) team creates strategic value for Boeing by leveraging innovative, external technology for internal development while stimulating investment returns.

DATA SOURCES

By exploring the confluence of technology gaps, opportunities to augment existing core businesses, and the utilization of portfolio company expertise in products, services, and technologies this thesis attempts to analyze how the creation of a Corporate Venture Capital team can harness innovation to support internal company development and stimulate investment returns.

Data Types and Format

Data will be synthesized from meetings, workshops, informational interviews (Boeing 1:1 meetings), company briefs and websites, PortCo visits, literature review, and conversations with other CVCs.

Author: Jomi Kramer

IMPACT

This thesis will examine how a large company can effectively leverage external innovation for internal success. In an effort to stimulate the ideation process and internalization of bold innovations, a company can implement a Corporate Venture Capital (CVC) Team to evaluate, transition, and develop external innovation for internal company growth. A successful CVC understands the needs of the parent company, captures external VC opportunities, and facilitates the transition of new technology to support core business growth and develop industry innovation. Although innovation often answers the question of what we can make, it is even more important to pause and ask how we can best develop and implement innovation for it to fully capture monetary and strategic value. By investigating the pathways through which innovation ideas evolve from a concept to fully integrated products, it is apparent that each method has its own merits and challenges. A properly established CVC team can help facilitate the exploration and implementation of external innovation. Because business is not conducted in a vacuum, even if you believe you have the right ideas in place, it will only work if everyone is aware of the guiding principles. Thus, establishing a best practice to create a repeatable and scalable process is imperative for CVC value creation success. Furthermore, the revelation that a CVC is essentially an internal sales team towards internal stakeholders creates a new framework.

DRIVERS	**Building off of extensive literature that attempts to answer the question of if a CVC creates value for a company by analyzing performance results and recognizing the distinct differences in investment strategy between independent venture capital and corporate venture capital, this thesis will instead attempt to analyze how a CVC can leverage external innovation to create strategic value through technology investments.**
BARRIERS	**In an effort to embrace the agile nimbleness of a startup, a CVC may assume that creating internal processes will hinder their ability to act alongside a portfolio company. Naturally, to act more similarly to an independent VC a CVC may want to shy away from large, corporate processes. However, it is important to create a common foundation for the CVC where everyone knows what is expected and how best to accomplish these objectives.**
ENABLERS	**A large company should look to develop long-term partnerships to augment existing core business needs and utilize a startup's agility, products, services, and technology for future commercial growth opportunities. If there is an opportunity to expand the technology beyond their own company, a CVC can create spinoffs or external partnerships.**
ACTIONS	**Although innovation often answers the question of what we can make, it is even more important to pause and ask how we can best develop and implement innovation for it to fully capture monetary and strategic value. By investigating the pathways through which innovation ideas evolve from a concept to fully integrated products, it is apparent that each method has its own merits and challenges.**
INNOVATION	**In an effort to stimulate continuous improvement and growth, a company can implement a Corporate Venture Capital Team to evaluate, transition, and develop external innovation for internal company growth. A successful CVC understands the needs of the parent company, captures external VC opportunities, and facilitates the transition of new technology by creating mutual growth opportunities internally and with a startup.**
IMPROVEMENT	**With a sound operating strategy, a large company can leverage the strengths of strategic investments. Furthermore, the revelation that a CVC is essentially an internal sales team towards internal stakeholders will provide a new framework and insight to effectively engage internal stakeholders and capitalize on external innovation for mutual growth opportunities internally and with a startup.**
BEST PRACTICES	**Establish a best practice, document the way of work to create a process for repeatability and scalability; evaluate, transition, and develop ideas to leverage external innovation through strategic investments to create mutually beneficial commercial growth applications.**
OTHER APPLICATIONS	**Strategic investments, Venture Capital, Corporate Venture Capital**

Logistics / Distribution | Retail | Inventory management / control | Linear / Non-Linear

Planogram Optimization in Support of Small Format Retail Inventory Management

BUSINESS PROBLEM

Planograms (POGs) are designed by Merchandising with a focus on presentation and the in-store guest experience. This results in POGs that may be over/under-sized for the desired levels for replenishment, resulting in incresed inventory levels which impact backroom space and store labor. On the other hand, decreased inventory levels can increase the frequency on stock out events. These challenges are more stated in Small Format stores which offer a limited selection of SKUs in sales environments with restricted shelf space and limited backroom capacity.

APPROACH

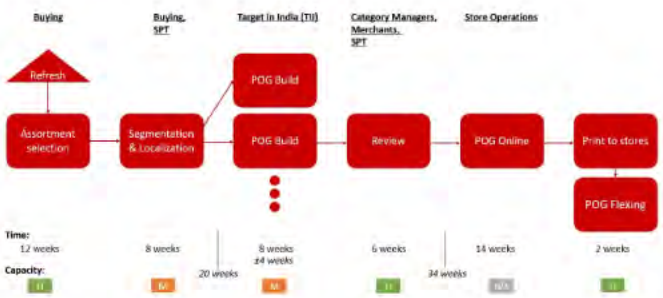
A mixed-integer linear program will be developed to maximize a 'Fit' objective function. This objective function will aim to minimize the risk of backroom inventory (which increases operational cost) while avoiding out of stocks (impacting customer experience). This will be considered through the lens of constraints around a strategic and focused assortment, such as product performance.

DATA SOURCES

Data is sourced from Hadoop by leveraging SQL queries and manipulated as dataframes in Python. Most data is quantitative or categorical, with limited unstructured qualitative data.

Data Types and Format

Data consists of inventory metrics and buying behavior collected a product, store, and date level.



Author: Miles Kurtz

IMPACT

The optimization model provides the business with a novel way to incorporate Inventory Management considerations in POG design. By quantitatively defining 'Fit' as an objective function, a mathematical target can be minimized programmatically. This reduces the manual burden to optimize POGs and allows more individualized POGs to be built. Furthermore, by characterizing POG design using a value chain map, the points of inflexibility (bottlenecks) in the process become visible. To elucidate these areas of the recurring business process, the company can modify the process in minor ways in order to increase throughput of POG design. The impact of reducing bottlenecks is increased quality in this case (more time to review for errors), having a positive impact on the business. A final lasting impact of this solution is the ability to evaluate future in-store interventions by using Synthetic Control Design (SCD). Introducing the application of a new tool can allow experiments to continue in smaller populations of stores or stores where controls may not be easily accessible.

DRIVERS

In Summer of 2022, when this research began, supply chains had reacted to pent up consumer demand that occurred during Covid. Retailers were experiencing a surplus of inventory, and high inventory levels across the network included increased backroom inventory in stores. These issues were more prominent in Small Format stores due to their unique characteristics, making the research highly visible and important.

BARRIERS

Multiple selection criteria were necessary to align including an upcoming reset date for a POG, stakeholders eager to participate in our experiment, and a 'stable' category which experienced little variability or promotional activities.

ENABLERS

Target experienced many of the same challenges across the retail industry that led to a buildup of inventory. As a result of this dynamic, merchandisers were perhaps more focused on Inventory Management than they would have been previously. As this project offered a solution to inventory issues in stores, team members were willing to provide time and expertise to further this project.

ACTIONS

To implement the solution, it was critical to partner with stakeholders in merchandising, space planning, and at the store level. By meeting with team members and visiting stores, the vision of this work was clear and able to be implemented.

INNOVATION

This solution quantified 'Fit', a concept that is frequently discussed within Target but did not have a common definition. By defining Fit as a weighted average of backroom inventory risk and demand coverage, an innovative mixed-integer linear program could be built. Furthermore, the output of the model was evaluated with a novel statistical method, Synthetic Control Design (SCD).

IMPROVEMENT

The lift in unit sales provided by the intervention was not deemed to be statistically significant due to idiosyncratic noise in the sales data. However, the optimization methodology was incorporated into an existing POG design tool and stakeholders invested in the project are evaluating POG design based on the value chain developed as part of this research.

BEST PRACTICES

The best practice employed here was to select specific categories that exhibited stability (to focus on less variables) and specialize in these areas. This ensured that the optimization model met the dynamics of each business; while a future researcher can select any category, they should know it very well and adapt the model accordingly. For example, in a home category, a researcher may want to account for the compression level of pillows.

OTHER APPLICATIONS

Other potential applications of this solution include any optimization problems which follow the same structure as Knapsack Problems, but have additional constraints. Furthermore, objective functions with multiple weighted considerations could adopt the methodology of this research.

R&D | Aerospace and defense | Product design and testing | Regression analysis

Model-based Technology Roadmapping for Sustainable Aviation

BUSINESS PROBLEM

As the aviation industry aligns towards net zero commitments, a new generation of aircraft will need to be introduced around 2035. Airplane program timelines from announcement to first delivery have grown since the turn of the century to 15-20 years while the foundational technology for low-emissions aircraft (batteries, fuel cells, cryogenic engines, etc.) is still immature and unproven in commercial flight. Technology roadmapping is a critical tool but is often qualitative and inflexible. A quantitative, flexible methodology is needed to identify key technology sensitivities and improvement.

APPROACH

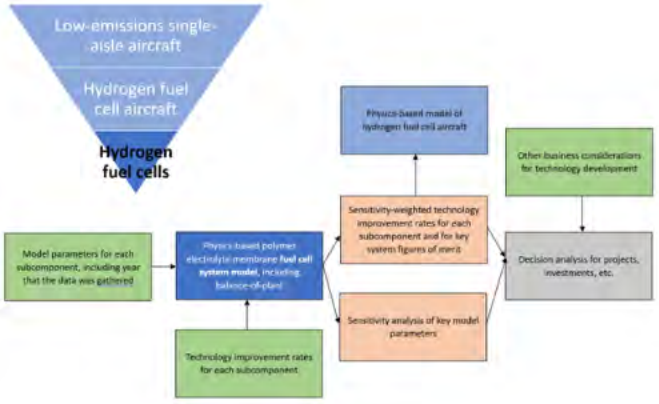
This project used the Advanced Technology Roadmapping Architecture (ATRA), focusing on figures of merit and their improvement. We build a methodology that can be used to evaluate sensitivities and project improvement rates in a system, using polymer electrolyte membrane hydrogen fuel cells as a pilot case. This approach links research in technology improvement to first-principles system models.

DATA SOURCES

Hydrogen fuel cell model parameters - academic papers, prior work in fuel cell modeling Hydrogen fuel cell performance data - manufacturer specification sheets, industry reports Technology improvement rate estimates - technologyrates.mit.edu

Data Types and Format

N/A



Author: Lisa Liu

IMPACT

Developing new products relying on maturing technologies is risky, particularly in an industry where product development cycles are long and costly. The next generation of sustainable aircraft will be using technologies that are still at low technology readiness levels. The approach developed here is scalable at different levels of detail for an aircraft and provides a quantitative method to identify key leverage points for technology improvement. A bottoms-up approach allows the user to model a system from first principles, conduct a sensitivity analysis, and combine this with improvement rates for each subcomponent. This approach yields a pareto analysis of the subcomponents and parameters that will both be most impactful for improvement and be most likely to improve quickly. Combined with a top-down approach looking at overall technology or system improvement rates, this methodology provides more detail to the user about key leverage points in the technology. This information can be used to develop an investment portfolio, conduct directed research, and work with supplier partners in product development. This methodology is more quantitative than other roadmapping approaches that rely on consensus opinion about how a technology may improve and can be used for a suite of technologies to evaluate options.

DRIVERS

The aviation industry has broadly aligned with net zero commitments and begun to develop new products with lower emissions. Boeing's Sustainability and Future Mobility team is working on identifying new aircraft concepts that could become future products. Many potential energy carriers are still being developed, though new products will be released around the 2035 mark. New approaches are needed to model technology improvement in systems.

BARRIERS

Technology roadmapping is not a standardized process and varies widely amongst groups at Boeing. The hydrogen fuel cell community is small and does not have a single model of best-in-class performance. Historical performance data was time-consuming to gather and difficult to find.

ENABLERS

This project has significant momentum within the team and support across stakeholders. It is well-aligned with aircraft modeling efforts that are underway, allowing the team to work and learn together. A number of people across the company had historical context on fuel cells, technology roadmapping, and corporate strategy that helped reveal potential pitfalls.

ACTIONS

The methodology was presented to the group at the culmination of the internship and turned over to the team. A new team member picked up the work about a month later, supported by the team manager and other teammates who had supervised the work.

INNOVATION

This methodology builds more detail into part of the ATRA technology roadmapping process. The process tests a novel, model-based approach to evaluating technology improvement levers by combining technology learning rates and physics-based models. The method also leverages a patent centrality method for determining technology improvement rates that dramatically reduces the resources required to find them.

IMPROVEMENT

The methodology shortens the time to determining technology improvement rates from weeks to minutes. It provides a quantitative approach to identifying key levers for technology improvement.

BEST PRACTICES

Determine the level of detail required to achieve the business objective – first-principles models may be too much detail if the components being modeled are outside the typical scope of supply for the firm. Identify the key interfaces with other projects and teams, including the inputs/outputs to the model needed and key stakeholders. Build alignment of stakeholders around the business process for building and maintaining the roadmap.

OTHER APPLICATIONS

This solution would be applicable in other industries with long and/or costly product development cycles. In these cases, being able to model future performance is helpful for informing potential investments, technology derisking efforts, and technology selection.

Supply chain planning and inventory management | Retail | Predictive forecasting | Clustering

Data-driven clustering for new garment forecasting

INDITEX

BUSINESS PROBLEM

The ability to detect patterns early in the design process is critical for fashion firms to make decisions, particularly given the speed at which new garments are introduced. Traditionally, most garment defining features were only used by designers and buyers in and since the data was intractable for a computer: shape, color, fit, etc. In particular, deciding on the size-curve distribution (percentage of smalls, mediums and larges) for a new garment relies heavily on finding a comparable, i.e. a previous garment that is similar to the previous one. Could this process be automated by using non-traditional data like the one described above?

APPROACH

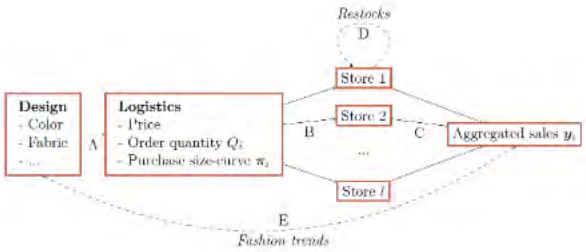
By using NLP techniques that preserve semantics we can extract the garment characteristics and create numerical embeddings of the garments. In tandem, we develop two custom algorithms for the fashion industry that leverage the dataset above to automate the comparable finding and simultaneously forecast the size-curve distribution.

DATA SOURCES

All the data comes from structured internal data sources that are easily queryable. However, there was a lot of data processing and wrangling to ensure that it could be used by the algorithms. In particular, the images and garment characteristics that were already encoded in a proprietary text format.

Data Types and Format

Rectangular data for time series of sales and purchases broken down by garment and size. Garment images for visual comparisons. Text descriptors that represent unique garment characteristics.



Author: Gianpaolo Luciano Rivera

IMPACT

The dataset itself: i.e. a vectorial embedding of the garments that preserves the defining is intrinsically valuable for a fashion firm. These embeddings are useful for computationally defining what similarity means in a sense that replicates what humans understand. Therefore, it has several applications, from item recommendations, cold-start clustering and performance indicators and forecasting tasks for new garments. More importantly, by using this data and framework we are automating the comparable process finding which can save hundreds of hours to the designers & buyers. Last, we show that the two forecasting algorithms can achieve close to human level results for the size-curve problem. Given enough data (to leverage as known comparables) it should improve baseline human performance.

DRIVERS

Understanding the established procedures and designing a solution that worked with the designers and buyers. Seeking to leverage their experience and know-how of the business in finding comparable garments. We weren't looking to replace them but to enhance their job and make it more seamless. In addition, the macro-trends of the industry that require even more expedited end-to-end (design-purchase-selling) experiences for the final consumers.

BARRIERS

Data quantity: the dataset test is just a small subset of what's available. To achieve human level results on the forecast, the algorithms need a complete set of all the garments of the firm. Data quality: the initial text representations of the garments might not be as granular to clearly capture all the details of the garments themselves which are critical for human level comprehension.

ENABLERS

The fact that Zara is a pioneer in the usage of data in the fashion industry, particularly in their supply chain & distribution processes. The data was readily available, albeit incomplete due to technical reasons. Similarly, the technical prowess of their analytics and data science teams is unrivaled.

ACTIONS

1) Interviews with the clients (buyers and designers of the garments) 2) Data data mining/processing to ensure the consistency across several seasons 3) Creation of a python package that queries/processes and standardizes the data. This package is extensible enough so that several machine learning models can be used in the forecasting algorithm easily

INNOVATION

1) Using a custom Natural Language Processing pipeline to embed the unique text characteristics of the garments that preserve hierarchical clusters, semantics and human level similarity 2) Development of two algorithms: Cluster-While-Regress (CWR) and k-nearest neighbors (kNN) algorithms tailored for the size-curve problem using the data above

IMPROVEMENT

Due to the data problem described above, there wasn't a quantifiable improvement in the operations of the firm at the moment. In the future when the framework and algorithms are improved, we will be able to give a concrete result that will come in the shape of savings.

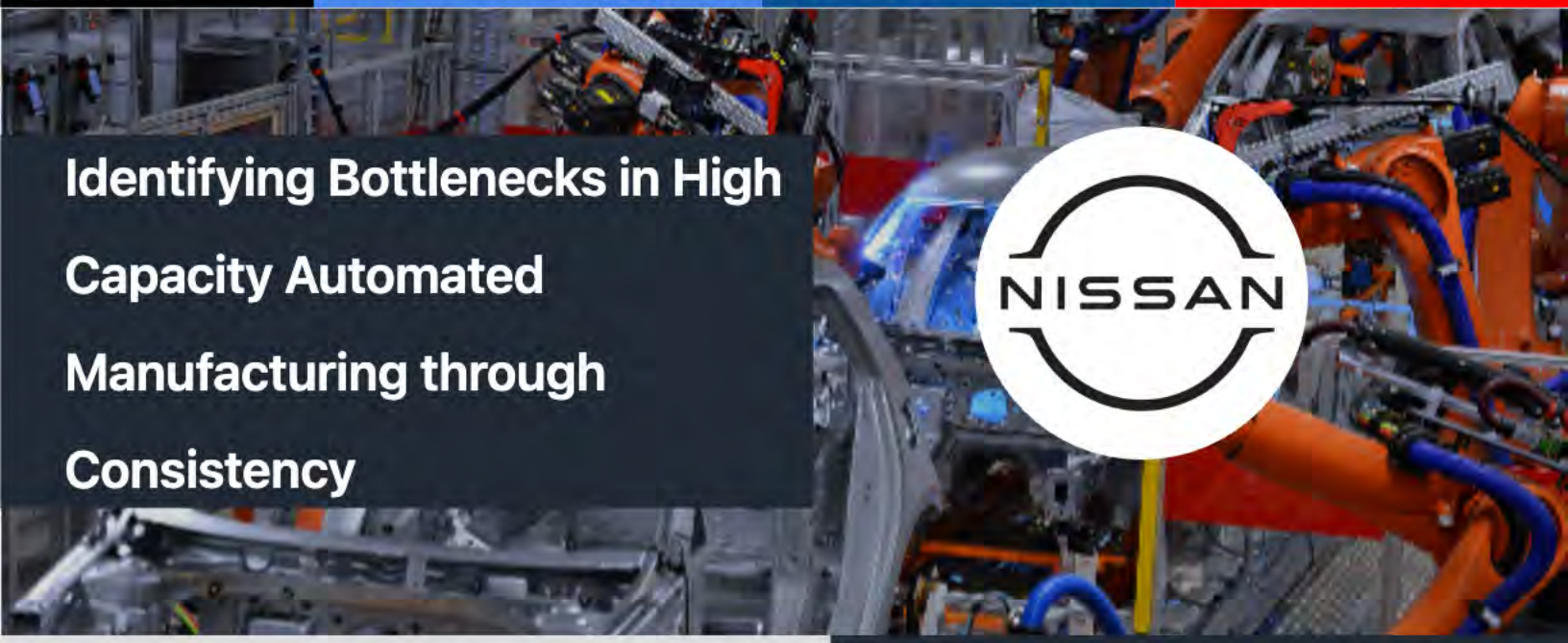
BEST PRACTICES

Making sure that there's enough data quantity: i.e. sufficient number of garments. And, data quality: ensuring that the text descriptors are sufficiently descriptive to capture all the details of the garments.

OTHER APPLICATIONS

The data structures can be used for: item recommendations, cold-start clustering, performance indicators and forecasting tasks for new garments. The algorithms can be used for any forecasting task

Manufacturing | Automobile manufacturing | Cycle time optimization | Discrete / Continuous



Identifying Bottlenecks in High Capacity Automated Manufacturing through Consistency

BUSINESS PROBLEM

Assembly lines can only produce parts as fast as their slowest process (the bottleneck). The bottleneck will govern the speed of production and implicitly set the maximum capacity of what can be produced in a given time period. Without making improvements to the bottleneck, production will never increase. In large complex automated manufacturing, it can often become difficult to determine which process is the bottleneck as there are thousands of processes happening simultaneously and random real-world events that also affect production rates. In order to improve production, operators require a quick and effective way to find the bottleneck.

APPROACH

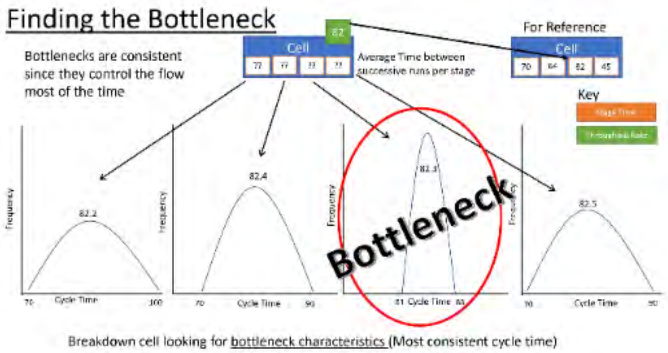
By selecting a single point in the process of a robot making a part, and timing until the exact same process is performed in the next part produced, you can break down the system to find the bottleneck. When comparing robots in series to one another, all robots will operate at the bottleneck's production rate but the bottleneck will operate at this time more consistently than any other robot.

DATA SOURCES

Timestamps of data strips, self reported by robots

Data Types and Format

Excel, Continuous, Histograms, Probability Density Diagrams, PowerBI



Breakdown cell looking for bottleneck characteristics (Most consistent cycle time)

Author: Kyle Lux

IMPACT

Enabling the finding of bottlenecks in a complex system, has drastically reduced the time required to find the bottleneck. Previous practice required several industrial engineers, with stopwatches, to go out and manually measure every robotic process in the plant. This took several days to perform and often did not lead to the actual bottleneck being found. Most of this inaccuracy was due to issues with manual timing of machinery. This new approach produced a dashboard that was updated automatically every hour, to identify issues in the plant. The new process takes less than 2 minutes by a single person once an issue is determined. An active decision was made not to fully automated the bottleneck finding process. Using this technique takes some finesse and understanding of what was going on in the overall system. This tool was designed to be an aid to human operators to streamline the time to find a bottleneck, verify issues found are the issue, and allow for additional time/resources to be applied to improving the bottleneck. This process found bottlenecks that were improved to increase daily production by 20 vehicles per day (4% increase).

DRIVERS

In order to improve production, you must improve your bottleneck. If the bottleneck is unknown or difficult to find, you will end up wasting resources improving areas that do not increase production capability.

BARRIERS

Data is the most important part of this analysis. It is important to understand what your data is measuring and where it is coming from. Without a consistently measured datapoint, it is not possible to perform this analysis. Due to limited time and research, this analysis can currently only be performed on single product assembly lines.

ENABLERS

The people where the biggest enablers. Without the support of management on this project, I would not have been able to succeed. Everyone at Nissan was excited for the new tool when it was rolled out and embraced the change.

ACTIONS

In order to ensure continuity, I tried to make the tool as easy as possible to use. First, I created an easy to access dashboard that could be seen anywhere in the plant. Second, I ensured the dashboard would be auto populated with new data as frequently as possible. Finally, I held classes to teach operators how to use the new tool and recommended a frequency of use that made sense based on their role in the plant.

INNOVATION

This process can be implemented almost immediately in automated manufacturing facilities that produce only a single product on their assembly line. The main datapoint used to perform this analysis is the timestamp associated with the report most robot automatically send off after each production cycle. So long as this data is collected and presumed accurate, the analysis can be performed.

IMPROVEMENT

Identified bottlenecks were improved to increase production by 20 vehicles per day, a 4% production improvement. Additionally, in the first 2 weeks of operation, the dashboard identified over five abnormal conditions that were systemically impacting production. Some of these events persisted for multiple days and resulted in a real loss of over 100 vehicles. All conditions were fixed once identified.

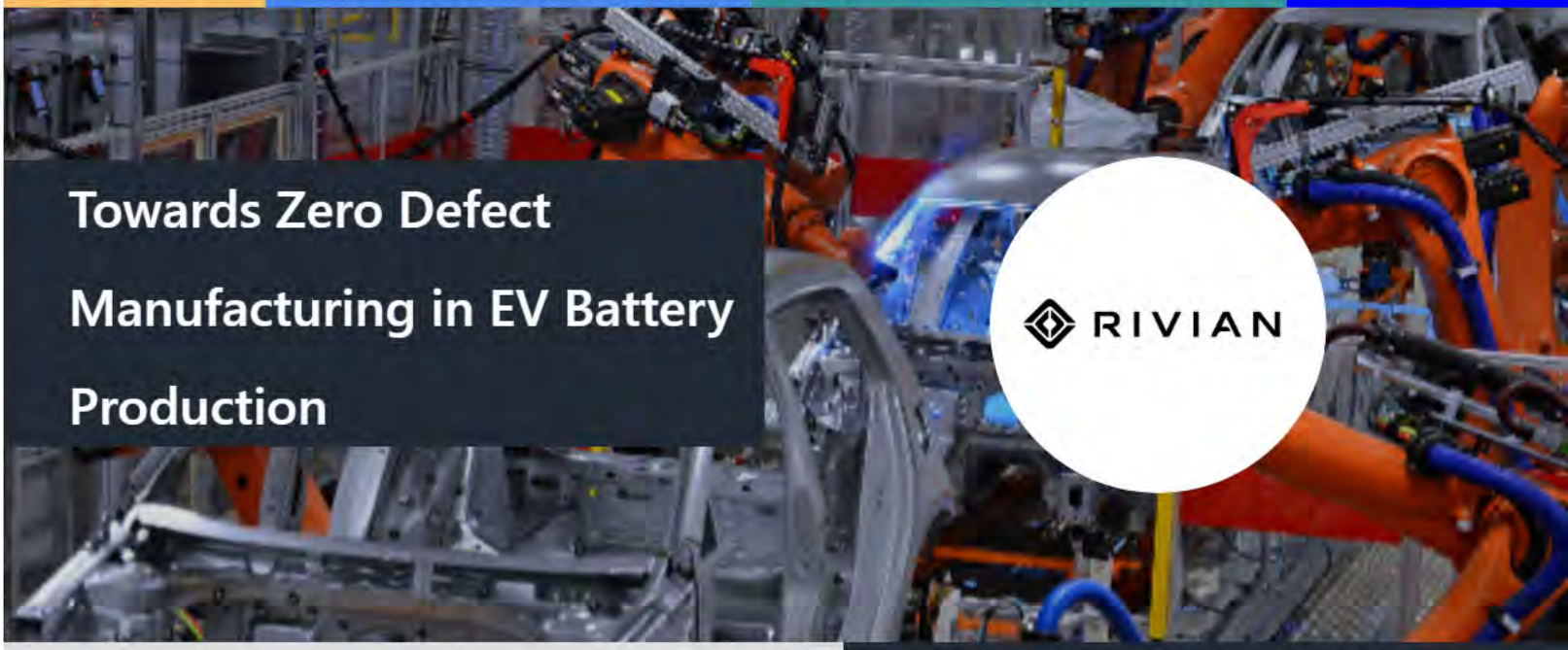
BEST PRACTICES

First, understand your data. This process can not be replicated with bad data and will lead to incorrect bottleneck identification.

OTHER APPLICATIONS

This solution can be implemented in any system that produces a single product, using mostly automated processes. There is a need to also have a database collecting the information for analysis.

Quality | Automobile manufacturing | Improved process performance | Classifiers



Towards Zero Defect Manufacturing in EV Battery Production

BUSINESS PROBLEM

In June of 2022, Rivian's battery module production lines were generating defect rates above stated targets, with much of the nonconforming material being nonrepairable and ultimately scrapped. The battery shop did not have sufficient tools and processes in place to systematically measure and analyze the root cause of defects. Therefore, management was unable to efficiently allocate resources to resolve quality issues. The primary objective of my project was to improve the quality measurement system and reduce the scrap rate of work-in-process and built battery modules in order to ultimately improve throughput of vehicles.

APPROACH

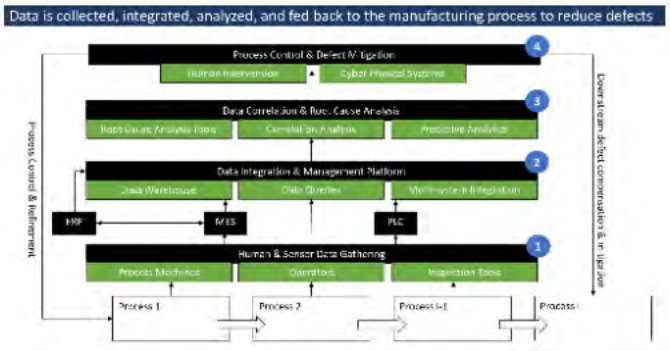
The first step of the project was to perform data analysis and establish a process that reliably captures key information on nonconforming materials generated by the battery shop's production lines. The second step was focused on testing and evaluating which quality improvement methodologies were most effective in reducing the occurrence of defects leading to rework or scrap.

DATA SOURCES

Rivian houses data related to scrap in several different locations. Data includes information on scrapped orders, part names, serial numbers, costs, and scrap reasons. One gap that originally limited reporting capabilities from the Manufacturing Execution System was reliable, real-time information regarding potential scrap from the production line.

Data Types and Format

Data was primarily tabular. Imaging and video data was also available when targeted root cause analysis was required. Sources included ERP, manufacturing execution, and document storage systems.



Author: Taylor Lyberger

IMPACT

1. Data Quality • Achieved stronger alignment across multiple data sources, such as the daily scrap count records in MES, ERP, and outbound shipping manifests. • Defined mutually exclusive and collectively exhaustive categories for key data attributes, resulting in a more streamlined data management process. 2. Real-Time Defect Detection • Introduced control charts to detect assignable cause variation in output parameters. • Coordinated implementation of logic and alarms to stop the line or alert an operator live when a defect was detected, preventing downstream propagation. 3. Standard Process Adherence • Documented process maps and step-by-step guides to clarify process ownership and to train team members on standard processes. • Developed metrics and dashboards to measure process adherence for use by management to address gaps in a targeted fashion. 4. Data Analysis Repeatability • Shifted the team's time investments from data generation and analysis to data interpretation and action planning. • Leveraged the data integration platform to automatically refresh and update analysis output. 5. Scrap & Defect Rates • Active project management and communication across teams allowed the battery shop to recognize and prioritize solutions to address quality issues. • Despite a rapidly increasing production rate and increasing material prices, scrap costs decreased from the project start date to the project end date as a result of the quality improvement program.

DRIVERS

The project kicked off at an inflection point during the production ramp period. The rate of nonconforming material generation was no longer sustainable from both a cost and physical material handling perspective. All levels of the organization became fixated on reducing rework and scrap costs, therefore leading to more time and resources being shifted towards quality improvement activities.

BARRIERS

1. Technical Capabilities: Improvements to data collection and defect detection systems required IT and contractor involvement. Proposed solutions could not always be immediately implemented given limited resource bandwidth. 2. Communication: This project required cross-collaboration from management, engineering, and operating teams. There were not initially channels set up for these groups to communicate in an organized manner.

ENABLERS

1. Agility: Given that Rivian was still ramping production of battery modules and building new lines, the organization was used to frequent changes and therefore open to implementing new ideas without unnecessary red tape. 2. Engineering Talent: Once quality data become more easily visible and interpretable, qualified engineering resources were available to effectively brainstorm and implement solutions.

ACTIONS

1. Process Changes: Made changes to both the digital systems and the physical flow of materials to improve data collection efficiency and accuracy. 2. Dashboard Development: Visualized defect and scrap data for repeatable consumption by both management and operators. Project Management: Drove action by assigning clear ownership and deadlines for specific defect mitigation tasks.

INNOVATION

This project was innovative in the identification of defect mitigation methods. While some defects were easily resolved by tuning machine parameters, others were not as easily controlled. Sometimes eliminating defects required upstream process alterations, equipment re-engineering, or changes to product design. For example, altering the size of the buffer upstream from adhesive press had the potential to reduce adhesive cure timeout defects.

IMPROVEMENT

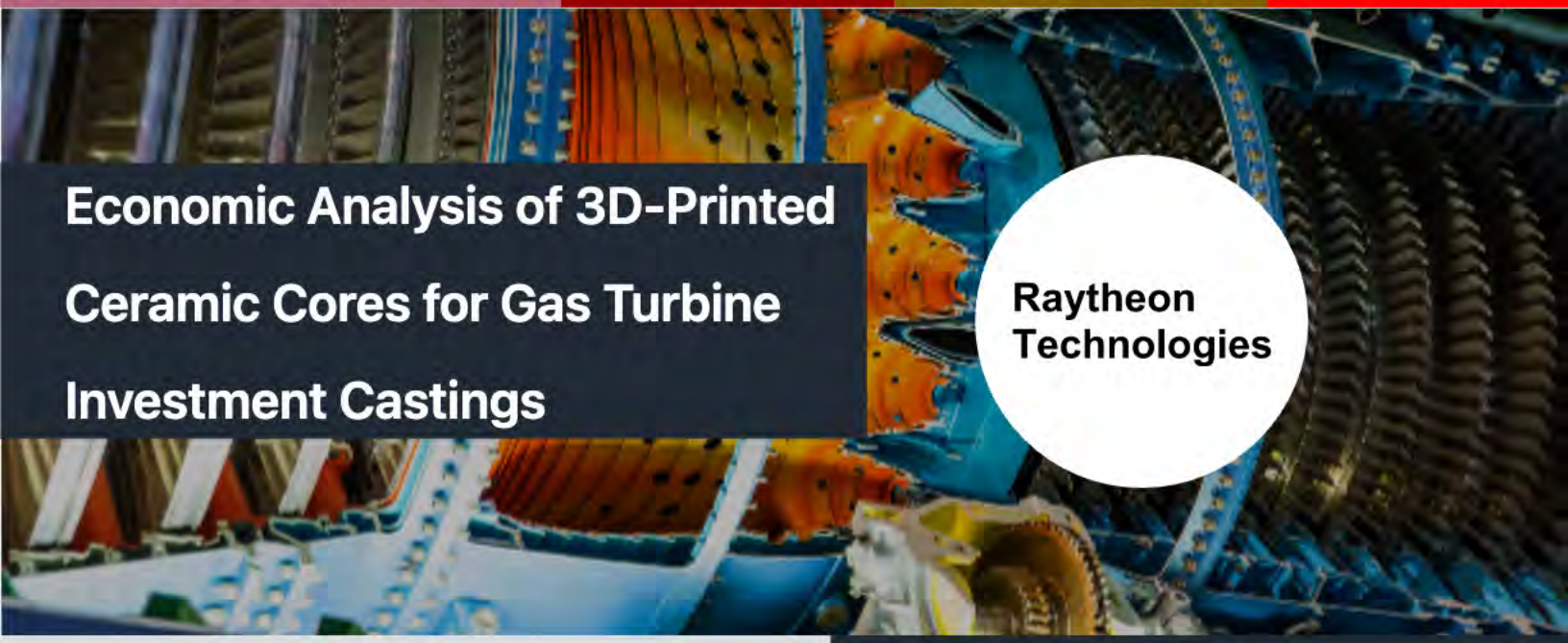
Despite a rapidly increasing production rate and increasing material prices, total monthly battery module scrap costs decreased from the project start date to the project end date as a result of the quality improvement program. Additionally, this project identified a single source of truth for battery shop scrap data to perform both defect root cause and financial costs analyses.

BEST PRACTICES

1. Designate quality champions outside of the quality team. 2. Create a cadence that gathers cross-functional teams to develop solutions that consider upstream and downstream effects. 3. Clearly define and prioritize the set of technical requirements that must be met to implement solutions. 4. Consider cost, urgency, and in-house capabilities to build a realistic road map of technology implementation.

OTHER APPLICATIONS

This quality improvement framework can be applied in any manufacturing environment. It is particularly applicable when running recently implemented production lines in order to rapidly identify any negative unintended consequences of both product and production line design choices. The framework provides a step by step process for management to develop quality improvement processes that match the capabilities of their organization.



Economic Analysis of 3D-Printed Ceramic Cores for Gas Turbine Investment Castings

Raytheon Technologies

BUSINESS PROBLEM

When manufacturing blades and vanes for gas turbine engines, internal cooling channels are formed by investment casting with sacrificial ceramic cores. The hot injection and pressing techniques traditionally used to manufacture ceramic cores have long lead times and high up-front costs, motivating an interest to form cores via additive manufacturing. While industrial additive manufacturing technologies enable a faster and more iterative ceramic core manufacturing process, this efficiency comes with high per unit manufacturing costs of additive methods.

APPROACH

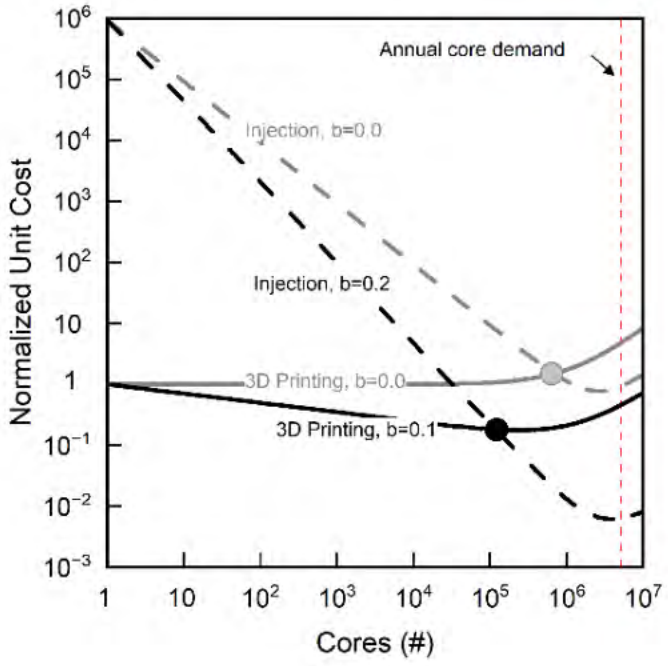
To determine the quantities for which additive manufacturing is more economical than traditional hot injection and pressing methods, an economic analysis of the aircraft engine and investment casting markets was conducted. To determine the technical feasibility of using additive manufacturing, current technical capabilities of several additive methods for forming ceramic cores were compared.

DATA SOURCES

Publicly available financial data from aircraft engine OEMs and casting companies, metal commodities prices, aircraft fleet sizes, industry reports, and aircraft MRO information.

Data Types and Format

Financial statements, industry reports, fleet size data.



Author: Eduardo Maristany

IMPACT

The economic advantage of using viable additive manufacturing methods was assessed using publicly available financial, maintenance, and aircraft fleet size data in a manufacturing cost model. When considering user experience curve effects, the model shows that for a single core design, additive manufacturing is economical at quantities below 1,900 cores, or about 16 high pressure turbine stage sets. When considering multiple core designs needed to satisfy demand across all commercial aircraft in use, the model shows that additive manufacturing is economical at quantities below 720,000 cores, or 14% of the total core market demand in 2019. This motivates the use of additive manufacturing for new core design development and testing as well as the maintenance of older engine designs while reaffirming the use hot injection and pressing techniques for production level manufacturing and maintenance.

DRIVERS

The lack of competitive pressures in the casting industry, the high cost of developing and manufacturing the steel dies, and low yields of intricate, hot pressed ceramic cores motivates the use of alternate manufacturing processes. Traditional subtractive machining processes are not suitable given their incompatibility with ceramic materials traditionally used for cores, making AM a promising approach.

BARRIERS

The fact that the airfoil casting industry is essentially a triopoly also means that a lot of their actual manufacturing costs and airfoil pricing structure is obscured to outsiders, and potentially, to their customers. This lack of transparency makes it particularly challenging to extract the true manufacturing cost of the actual ceramic cores, since they are essentially a sacrificial tool in the process of manufacturing airfoils.

ENABLERS

Speaking with several airfoil casting experts at Pratt & Whitney allowed me to focus on the right data in order to be able to extract a cost estimate for ceramic cores. Along the same lines, speaking to additive manufacturing experts at Pratt & Whitney allowed me to focus on the right additive processes.

ACTIONS

The original plan for this internship was to either commission ceramic AM test articles or print parts in-house in order to verify the three ceramic core requirements. Four suppliers were selected based on their availability of ceramic printing materials that would have a high likelihood of being easily leachable. Quotes were obtained from all four suppliers, but unfortunately no parts were able to be delivered before the end of my internship.

INNOVATION

The model developed found that AM is most economically advantageous at low, pre-production quantities. This is in line with most other uses of AM as prototyping method rather than a mass production one. However, the rapid fabrication times for additive manufactured cores presents a great opportunity to utilize AM in the development of new HPT blade and vane designs, without having to commission prohibitively expensive and long lead time dies.

IMPROVEMENT

As AM technologies keep improving, the cost of printers and print material goes down, and the size and print speed of printers goes up, the model developed for this research can be utilized to find the most up-to-date break-even point of switching to AM. This would allow aircraft engine OEMs and MRO providers to continuously reassess the scale of their use of AM to manufacture ceramic cores.

BEST PRACTICES

The model presented in this report can be extended to analyze costs and demands for any given year, regardless of extraneous market conditions. Anyone trying to replicate the results just needs to make sure that their data and assumptions are in line with industry knowledge and best practices.

OTHER APPLICATIONS

Another area of consideration would be to assess the ability of aircraft engine OEMs to rent printing capacity—by ordering printed parts from a third party—rather than purchasing printers outright. The inputs of the model could be modified to remove this consideration and instead adjust the material and overhead costs to reflect the higher costs associated with contracting out to a third party with existing printing capabilities.

Maintenance | Aerospace and defense | Defect detection / product inspection | Classifiers

Autonomous Drone Assisted Aircraft Inspections

BUSINESS PROBLEM

The safety of the passengers, crew, and maintainers is the number one priority for any aircraft manufacturer or operator. Visual inspections of the exterior of aircraft is critical to the safe operation of aircraft, as defects such as corrosion, lightning strikes, or missing parts can compromise the structural integrity of the whole aircraft. Currently, aircraft visual inspections are conducted by human maintainers in a process that is not only time consuming, but also puts the maintainer and the aircraft at risk, as maintainers have to use lifts and cranes to inspect top portions of the aircraft, while walking along the wings and spine.

APPROACH

Maintainers use a laser based navigation autonomy enabled drone to capture aircraft inspection imagery. Captured images are then processed by a machine learning model, in order to identify defects on the external surface of the aircraft, aiding the maintainer in completing inspections in a more expeditious, thorough, and safer manner.

DATA SOURCES

Data available has been captured from proof of concept flight tests at Boeing facilities and various airlines. This data is in the form of the images captured by the drones during inspections, as well as metrics comparing the time to complete an inspection using drones compared to human-only inspections, and the accuracy of the drone assisted inspections compared to human-only inspections.

Data Types and Format

Data Types: Inspection imagery (database), performance metrics of time and accuracy of inspections (spreadsheets), output and performance of computer vision classification model (database).

Author: Andrew Mighty

IMPACT

The implementation of assisted autonomous drone aircraft inspections decreases the risks to inspection personnel and aircraft, decreases the time required to conduct inspections, and improves inspection record management practices through the data collection process. Additionally, the data collected during this inspection process can be used to improve inspection and repair practices as well as potential design of future aircraft platforms.

DRIVERS

In recent years, there has been an increase in research and implementation of drone systems to conduct inspections across multiple industries that have traditionally been considered time consuming and risky to inspection personnel. More recently, startups have begun working with commercial airlines to test the potential of implementing drone technology for the conduct of aircraft inspections.

BARRIERS

There were two major barriers that impacted the outcome of the project. The first barrier was aircraft availability and coordinating with aircraft operators to test AAI processes on aircraft that are likely to have sustained defects. Another significant barrier was data and imagery of defects available to train machine learning models due to current inspection methods not dictating a standardized imagery collection procedure for defects.

ENABLERS

The Applied Innovation team has unique access to all of the Boeing business units, working with multiple different groups to help find support for and to implement projects. Along with the team's ability to work across business units, the Applied Innovation team has access to portfolio companies outside of Boeing, quickly able to iterate on new technology concepts.

ACTIONS

Actions taken to implement the solution include conducting market research to identify potential market share, customer interest, and competitor solutions within the field. Following market research, a process workflow was designed implementing the use of machine learning damage detection software into the inspection process and validated through experimentation with inspection personnel to determine the effects of machine bias.

INNOVATION

The assisted autonomous drone aircraft inspection process proposes a new innovative solution to conducting aircraft inspections utilizing an autonomous drone to gather imagery of the exterior of an aircraft prior to processing the imagery through a machine learning model to identify damages and defects before the imagery is reviewed by an inspector through a user interface.

IMPROVEMENT

The final solution provides an inspection methodology capable of increasing inspection quality and accuracy while decreasing the time required to conduct inspections. Through a focused study on machine bias, the proposed solution reduces the potential of human factors negatively influencing inspection results.

BEST PRACTICES

Someone attempting to replicate this solution should take a step based approach to implementation, focusing on the data collection phases of ensuring appropriate quality and accuracy of data capture by the autonomous system prior to incorporating machine learning algorithms in the data processing phase. It is also important to dedicate the appropriate time to the development and execution of training programs for personnel.

OTHER APPLICATIONS

Drone assisted aircraft inspections can be utilized in multiple industries from construction, transportation, energy, and agriculture. The methodologies discussed for assisted autonomous aircraft inspections using drone platforms can also be applied to other industries using rover platforms suitable for those environment such as autonomous underwater drones for subsurface inspections.

Product design / development / engineering | Healthcare / Pharmaceuticals | Defect detection / product inspection | Graph-based neural networks

AI-assisted plausible reaction product and impurity structure prediction and elucidation

BUSINESS PROBLEM

Development of reaction schemes for small molecule synthesis is a key task of Process Development Team at Amgen. Most chemical reactions result in numerous by-products and side-products, apart from the intended major product(s). A priori prediction of all products is essential to ensure that the final drug substance is free from unintended impurities. While chemists can predict nearly all products of a single reaction step, tracking propagation of product/impurities along multi-step reactions becomes challenging. Conversely, identifying impurities post hoc from mass spectrometry data presents another significant challenge.

APPROACH

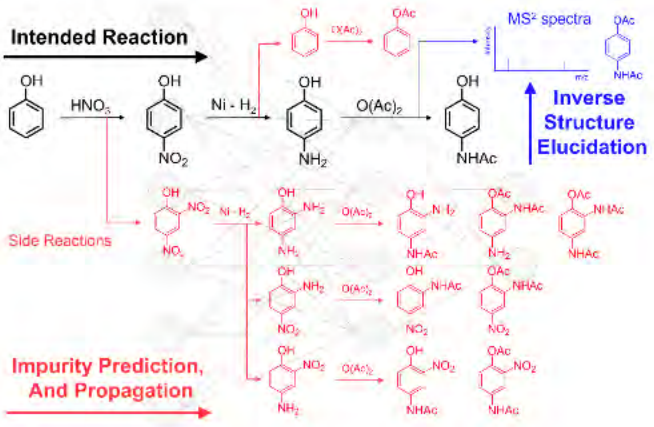
Impurity prediction will be done by modifying ASKCOS, an AI-based reaction predictor. The predictor will be run iteratively to track impurity propagation in multi-step reactions. For inverse structure elucidation, MSNovelist, a pre-trained ML model, will be adapted to predict molecules from mass spectrometry data. A user interface will be developed to assist chemists interact with the program.

DATA SOURCES

For impurity prediction, chemical reaction schemes for one or more Amgen projects in Process Development will be used to validate the tool. Benchmarking will be done by obtaining examples of selected named reactions from the literature. For inverse structure elucidation training and evaluation, MS2 data will be obtained from open-source databases, along with usage of proprietary Amgen data.

Data Types and Format

The reaction schemes will be received as ChemDraw files, with a document enumerating details for individual reaction steps. MS data will be received as m/z versus intensity, in a Microsoft Excel file.



Author: Somesh Mohapatra

IMPACT

The solution primarily impacts (1) identification of impurities, (2) high-throughput reaction screening, and (3) raw materials risk assessment, with all the steps being absolutely core to the synthetic drug substance commercial process development business at Amgen. Impurity identification, both a priori and post synthesis, aids process development, with the former helping in the optimization of reactions, and the latter in the identification of possible impurities in the product mixture. For high-throughput reaction screening, the tool helps in narrowing down the chemical space of possible reactions, balancing the exploration of a wide range of reactions versus exploitation of selected reaction pathways, thereby accelerating experimental efforts for route selection and route optimization. Additionally, the solution helps in assessing the risk posed by low-level impurities in raw materials – as purchased, reaction intermediates, and API starting materials.

DRIVERS

We are constantly striving for smarter, faster, better commercial process development. This tool could: (1) give us higher quality data from high-throughput reaction screening experiments, ultimately facilitating better understanding and long-term development of reaction data sets, and (2) save us significant time in critical structure ID task that come up through development and tech transfer.

BARRIERS

The biggest bottleneck in the implementation of the project was access to computational resources at Amgen, such as, installation of relevant software, getting access to servers, and administrative privileges. Accessing experimental data, both chemical structure and spectra, for computational purpose; and ensuring that the ML model complemented experimental knowledge of process development without being redundant, were the other challenges.

ENABLERS

Amgen is one of the best places that encourages intrapreneurial thinking, providing strong support to the interested folks to disrupt the status quo. The desire to be at the forefront of technological advancements, by leveraging both external and internal research and development, propelled the project. Additionally, the MIT MLPDS consortium and existing academic collaborations provided necessary technical support in advancing the project.

ACTIONS

In addition to the technological development of the codebase, training/testing of ML models, and validation of unseen data, conversation with people at Amgen and building relationships with people, both internal and external, helped in implementing the solution. The conversations helped in narrowing down the scope, and identifying the specific requirements of scientists and engineers, thereby ensuring that the solution is going to be more useful.

INNOVATION

Combining AI-assisted impurity prediction to form a candidate set of possible impurities, with the inverse structure elucidation model to down select from that candidate set, presents a paradigm shift in process development. This innovative approach saves significant amount of time and resources as compared to the current practice of involving subject matter experts for manual identification, and/or using commercial packages, such as, Virscidian.

IMPROVEMENT

The solution for impurity prediction helps in iterative evaluation of potential impurities from sources other than reactants and reagents, such as low-level impurities in raw materials. The inverse structure elucidation tool is expected to save a lot of time in identifying impurity molecules from spectra. In combination, both the tools are expected to be of significant help for process chemists and engineers and accelerate their current workflow.

BEST PRACTICES

The solution will comprise of a codebase with relevant comments. Replicating the work using the codebase should be done by installing the exact libraries, as used in the development, and following the instructions in the documentation.

OTHER APPLICATIONS

The solution can be used both before and after pivotal commercial process development, i.e., in pre-pivotal process development and technology transfer. In the pre-pivotal step, it can help in narrowing down pathways of interest by avoiding reactions producing higher amounts of impurity. The inverse structure elucidation can help in identifying unknown impurities from spectra and address any concerns around potential genotoxicity or mutagenicity.

Operations | Healthcare / Pharmaceuticals | Improved process performance | Regression analysis

Industry 4.0 in Biomanufacturing: Predictive Real-Time Models Using Process Analytical Technology

BUSINESS PROBLEM

Amgen's primary business is in manufacturing biologics, a process that involves growing mammalian cells in progressively larger bioreactors in a culture that induces them to produce the target protein. To ensure high quality, cell culture metrics like viable cell density (VCD) and viability are tracked via manual samples taken every 24 hours. Data from new sensors can be correlated to real-time readings of VCD and viability, leading to direct savings in avoidable product losses and reduced manual sampling, and creating opportunities for additional savings through optimization of the cell culture feeding strategy via advanced process control.

APPROACH

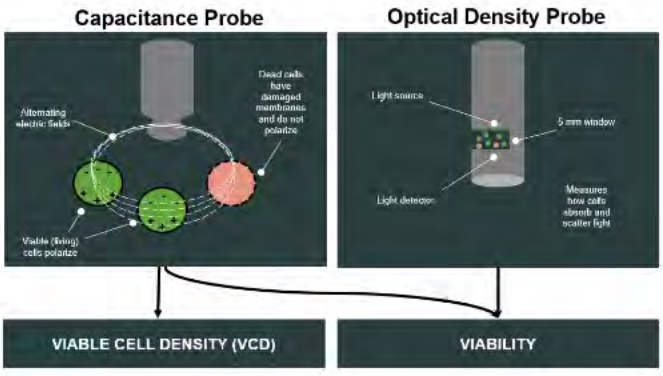
Multivariate analysis and supervised machine learning has been conducted on the data reported by the Process Development laboratories and pilot plants that are testing newer, more real-time sensors. The data from the sensors can be correlated to viable cell density (VCD) and viability, which are directly proportional to titer, the concentration of the target molecule in the cell culture media.

DATA SOURCES

The data are from Process Development laboratories and pilot plants located primarily in Cambridge, Rhode Island, and Thousand Oaks. A series of experiments have been conducted in these labs to test out the new sensors and models. Literature review is sources from both internal company white papers and external biomanufacturing sources.

Data Types and Format

Excel spreadsheets assembled by the labs consisting of numerical and datetime formats. Qualitative or categorical data is minimal outside of literature review.



Author: Michaela Elizabeth Murr

IMPACT

The models developed in this thesis enable real-time monitoring of viable cell density (VCD) and viability, currently done every 24 hours via manual sampling. This is an important component of a larger initiative to implement process analytical technology (PAT) to improve manufacturing efficiency at Amgen. Within the new $550M manufacturing plant slated to open in North Carolina in 2025, the implementation of PAT is projected to save $2M per year in avoidable product losses and reduce manual sampling by approximately 50%. Advanced process control (APC), which is improved by real-time data coming from the use of PAT, is projected to increase titer by 5% and result in $12M of additional savings per year.

DRIVERS

The FDA and global regulatory bodies encourage the use of PAT in biomanufacturing as part of their guidance to integrate with Quality by Design (QbD), a systematic approach to drug development that aims to ensure the quality of the final product by building quality into the development process. Globally, Amgen has been pushing to implement PAT, particularly in the construction of new biomanufacturing plants.

BARRIERS

A few barriers that impacted this work include limited data availability and regulatory risk. Given the small dataset size, traditional machine learning models that require large datasets are not well suited for this use case. Additionally, stringent regulations require full transparency into the model approaches and minimal external dependencies.

ENABLERS

This work is enabled by Amgen's company-wide strategy of driving toward Industry 4.0, resulting in careful planning and execution of the steps needed to thoroughly test PAT tools so they can be implemented at the new manufacturing facility in North Carolina and other facilities globally.

ACTIONS

To implement this solution, I worked closely with the process development scientists to understand the data and its context. We had weekly meetings where we reviewed the models together and I collected feedback. I also worked closely with others within the data science organization, resulting in broad testing and validation of the model approach.

INNOVATION

The implementation of these models will enable real-time cell culture analysis, where the current state is manual samples every 24 hours. The VCD model, being a gaussian process regressor, allows for a smaller training dataset, and can be used to make a confidence interval prediction instead of a traditional point prediction. The viability analysis is a novel approach that is being considered for patenting.

IMPROVEMENT

The implementation of process analytical technology in the new North Carolina plant is projected to save $2M in avoidable product loses and reduce manual sampling by approximately 50%.

BEST PRACTICES

Best practices for replicating this solution (e.g., training a model with new data coming from additional ongoing experiments at Amgen) include automating the data wrangling process as much as possible. I wrote python scripts that have been passed on to the data science organization to assist with this.

OTHER APPLICATIONS

PAT, specifically the VCD and viability models, can be used across Amgen's biomanufacturing plant networks, and other biopharmaceutical companies that produce biologics.

Product design / development / engineering | Technology | Product design and testing | Unsupervised Learning

On-Site Hydrogen Production via Distributed Methane Pyrolysis

BUSINESS PROBLEM

NextEra Energy is a major investor in energy infrastructure and clean energy technology, including clean hydrogen. To initiate their hydrogen program, NextEra Energy will build a 25 MW green hydrogen facility (made from renewable electricity) and invested in a large-scale producer of turquoise hydrogen (made from natural gas without CO2 emissions). Both of these are most affordable as large-scale centralized facilities, but current transportation and storage technology can make hydrogen cost-prohibitive for small-scale consumers. For these customers, a distributed hydrogen production method may be more desirable.

APPROACH

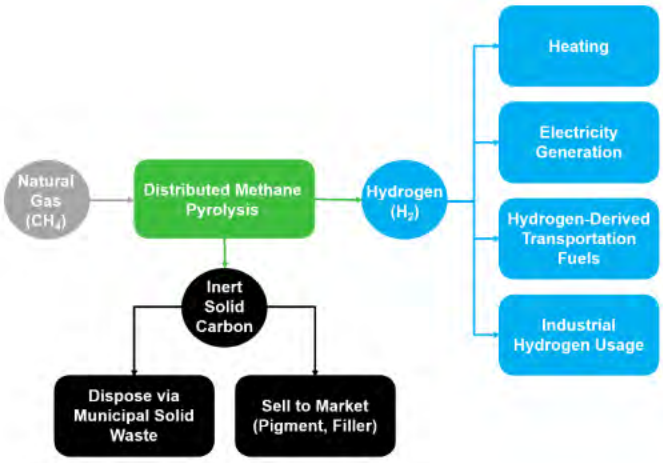
A novel method for producing low-emissions hydrogen from natural gas, known as methane pyrolysis, is unique in that it can be scaled down more economically for use in distributed hydrogen applications. This thesis provides an analysis of the economic viability and technical feasibility of this technology across several small-scale consumer applications, supported by a field demonstration.

DATA SOURCES

Publicly available historical data on residential, commercial, and industrial utility prices (electricity, natural gas, and liquid fuels) at the regional and state levels were utilized from the Energy Information Administration. Electricity costs were utilized from publicly available state-level government databases and select utility rate disclosures.

Data Types and Format

External utility data was exported in .csv format. Comparative economic data was in numerical format, mostly from conversations with stakeholders and through existing documentation.



Author: Madison Myers

IMPACT

This thesis identifies economically viable uses for distributed methane pyrolysis, particularly in difficult to decarbonize industries where geographical location and/ or cost constraints limit access to traditional renewables like solar and wind and low-emissions hydrogen from centralized sources. As NextEra Energy continues to pursue new clean energy technologies, this analysis will be key to guiding future investment in and implementation of distributed methane pyrolysis for low-emissions hydrogen production at the point of consumption.

DRIVERS

A major driver for this project was the need to identify strategic technologies which can economically address difficult to decarbonize sectors while simultaneously leveraging already existing resources.

BARRIERS

Barriers to project completion included limited access to state-level public utility data, especially for commercial customers, ongoing volatility with electricity and natural gas prices, and pricing uncertainty with several early-stage technologies included in the study.

ENABLERS

This project was enabled by broad support from NexEra Energy, particularly from my project supervisor and teammates. This included support for site visits to asses the technology and a willingness to engage in cross-functional collaboration within the company, especially between the Strategy and Product Solutions and Hydrogen teams.

ACTIONS

Worked closely with distributed pyrolysis technology developers to understand the technology and unit economics in order to identify market segments where systems could be successfully deployed. Collaborated with internal stakeholders to understand the hydrogen landscape and competing technologies.

INNOVATION

Two notable innovations with this solution are the use of distributed methane pyrolysis to generate small quantities of clean hydrogen on-demand, eliminating the need for storage, and the use of a methane pyrolysis system coupled with a hydrogen-compatible generator for arbitrage while simultaneously decarbonizing critical infrastructure.

IMPROVEMENT

Identification of three new markets where distributed methane pyrolysis can provide small-scale and intermittent consumers of hydrogen with a best-value hydrogen generation solution while simultaneously leveraging already existing natural gas resources. using this technology, low-carbon hydrogen can be generated in small quantities at the point of consumption for as little as $1.70/kg.

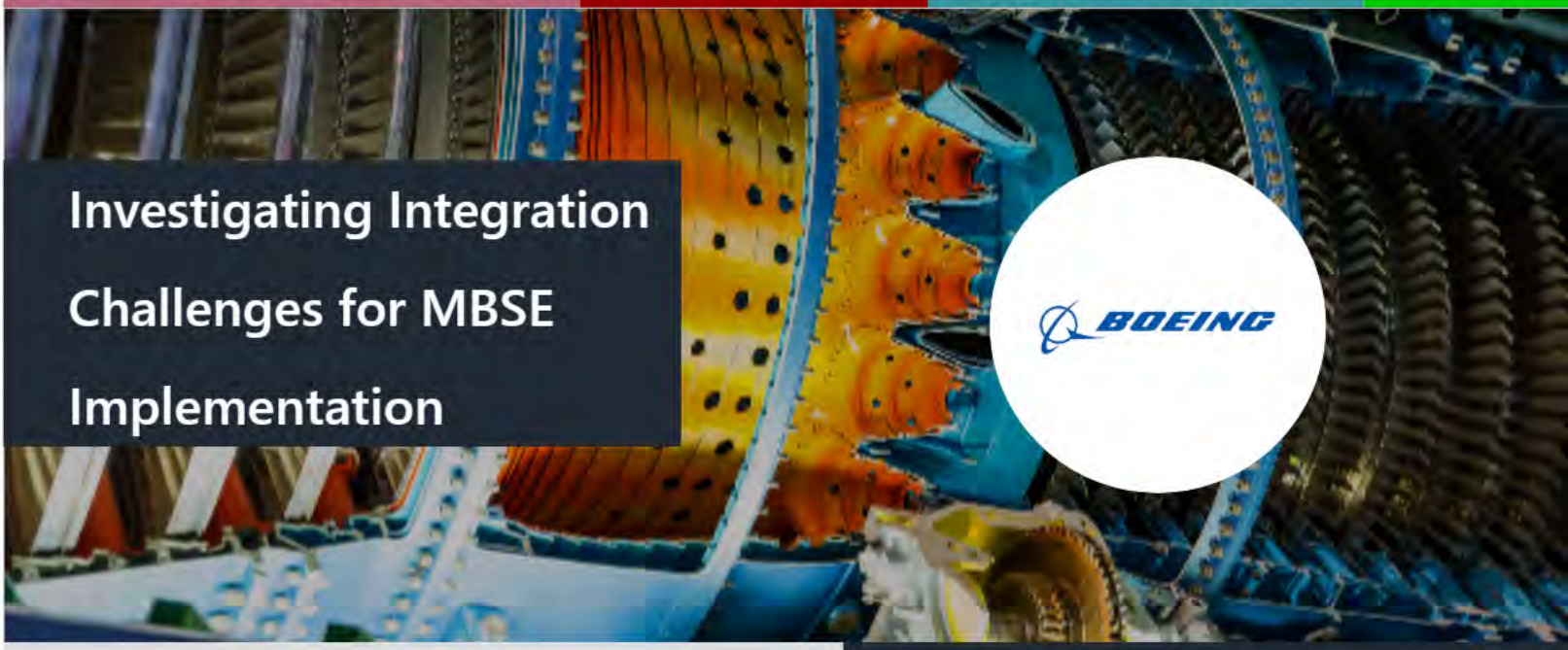
BEST PRACTICES

Ensure a thorough understanding of the competitive landscape and how different use cases impact economic and technical viability of competing solutions.

OTHER APPLICATIONS

This project approach is broadly applicable to evaluating and commercializing emergent technologies, both inside and outside of the clean energy space.

Product design / development / engineering | Aerospace and defense | Improved process performance | Rules-based



Investigating Integration Challenges for MBSE Implementation

BUSINESS PROBLEM

Adopting model-based systems engineering processes and tools have been difficult for the aerospace industry given system complexity, workforce needs, and perceived value. Integrating teams' processes and tools internally and externally remains one of the largest challenges both technically, and organizationally. To enable the value from MBSE, understanding an approach to these integration challenges is critical to Boeing, and the on-time delivery and quality of its future product. Standardizing the integration of the system development environment enables consistent and complete information flow as well as supply chain collaboration.

APPROACH

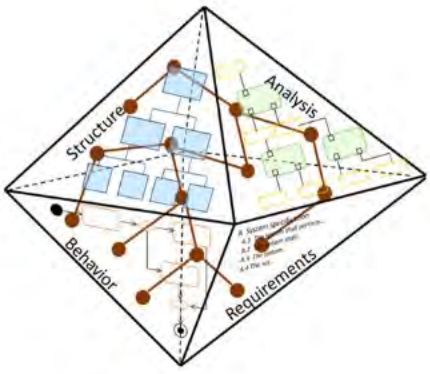
A case study approach was taken to understand challenges based on local deployment across multiple programs associated with a defined system model integration use case. A survey was conducted to capture these challenges at scale. To generalize the challenges and characterize needs, a comparative analysis against NASA was completed to validate a framework and generate recommendations.

DATA SOURCES

Data was gathered from multiple teams using MBSE methods across functional disciplines associated with the identified use case as well as from an organizational survey, interviews across engineers, managers, and leaders in the organization and through team participation.

Data Types and Format

Data took the form of interviews, observations, workshops, directed questions, an organizational survey, physical documentation, and published papers.



Zwirner, Dirk. February 2020. "MBSE and Integration." Retrieved August 8th, 2022 from: https://intercax.com/2020/02/20/mbse-and-integration-part-1/

Author: Jenn Pandolf

IMPACT

Suggests a framework for looking at model integration challenges to generate recommendations, which provide the basis for accelerating integrated MBSE deployment to address concerns relative to internal and external integration across multiple domains. Model integration can provide improved quality and delivery pace based on increased communication and consistency of system understanding, resulting in less costly requirement churn.

DRIVERS

Model integration can provide improved quality and pace through increased communication and consistency of system understanding during development. Integrated MBSE approaches enable digital engineering initiatives for managing risk throughout the life of development programs

BARRIERS

Silos across large organizations make it difficult to find use case examples. Common use of MBSE terms and the perceived value of deployment make it difficult to distinguish and discuss challenges across teams, and across company boundaries. Comparative analyses rely on defined terms and common usage.

ENABLERS

Experts throughout the company provided insights into the challenges from multiple different perspectives that shed light on the difficulties with MBSE across teams, company boundaries, and across the industry. Team participation improved understanding of these challenges and made frustrations feel very real.

ACTIONS

Discussions with relevant stakeholders based on the observed challenges and the proposed recommendations provided insights into potential next steps. Comparative analysis against a similar well-documented organization built the foundation for the framework and generated recommendations.

INNOVATION

To enable system model integration, recommendations should consider both technical considerations and organizational considerations. A framework for considering more than tool and process interoperability provides insights into needs for integration success. Recommendations consider all of these areas to accelerate deployment with considerations for adoption and technical integration.

IMPROVEMENT

Framework for assessing integration challenges to determine improvements and general recommendations for accelerating MBSE deployment at scale from both an organizational and project perspective with the intent to improve model integration.

BEST PRACTICES

Surveys should allow large free response fields to better capture the context of feedback. Interview as many stakeholders as possible to provide insights from different perspectives relative to deployment. Team participation enabled additional observations and understanding of evolution of challenges.

OTHER APPLICATIONS

Framework and recommendations are relevant for any diverse organization looking to deploy model-based systems engineering (MBSE).

Maintenance | Healthcare / Pharmaceuticals | Improved process performance | Rules-based

Ontology-driven AI for optimizing maintenance operations

BUSINESS PROBLEM

The main problem Amgen aimed to solve was the inefficiency in managing asset maintenance in biomanufacturing operations. The challenge lies in that essential maintenance details within maintenance work orders (MWOs) are often stored in unstructured text fields, making it difficult to extract insights automatically. This leads to engineers' reliance on time-consuming manual analysis, which could be more cost-effective and hampers the overall efficiency of asset maintenance management.

APPROACH

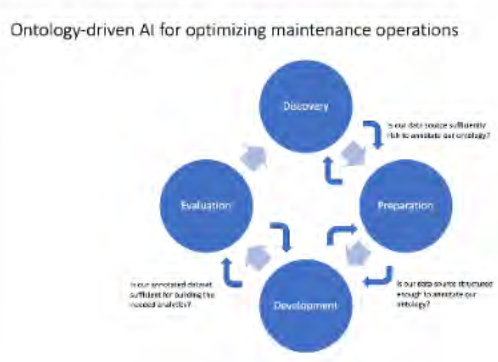
We initiated the process by gathering the analyses required by the reliability engineering teams. Based on these analyses, we identified the data needs, encompassing structured and unstructured information. We then created a comprehensive ontology incorporating all the relevant data and developed a natural language processing (NLP) tool to handle the unstructured data efficiently.

DATA SOURCES

The Maximo data set includes structured and unstructured data. The structured data consists of the spare parts used, labor hours required, and the asset worked on. The unstructured data includes free text from technicians and engineers. The free text is written in multiple languages and is not standardized.

Data Types and Format

The Maximo data set includes structured and unstructured data. The structured data consists of the spare parts used, labor hours required, and the asset worked on. The unstructured data includes free



Author: Gabriel Pascualy

IMPACT

Our solution could significantly impact Amgen's business operations, particularly in asset maintenance management in biomanufacturing processes. By developing a unified ontology that integrates both explicit and implicit maintenance ontologies found in MWOs and creating an NLP tool to reconstruct this ontology from structured and unstructured fields, we were able to streamline the process of extracting valuable insights from MWO data. The primary benefit of our solution is that it could substantially reduce the time engineers spend on manually analyzing work order data. This reduction in time spent on analysis translates into cost savings for the company. It frees engineers to focus on more value-added tasks, ultimately improving overall productivity and efficiency in managing and maintaining assets. Furthermore, the unified ontology and NLP tool could provide insights into plant maintenance operations, enabling the company to make better-informed decisions regarding maintenance tasks, resource allocation, and equipment lifecycle management. This increased visibility could lead to improved asset reliability, reduced downtime, and optimized maintenance schedules, critical factors in minimizing operational disruptions and maximizing production output.

DRIVERS

Amgen has used a computerized maintenance management system (CMMS) for over a decade to track and manage work in their manufacturing plants. The CMMS was not intended to be used for analytics and therefore, much of the data is captured in free text. Recent advances in language models and an internal maturation of Amgen's data platform were catalysts for this solution.

BARRIERS

The biggest barrier to this project is the general expectation that machine learning and NLP can solve problems without a deep understanding of the problem space and its underlying ontology. Convincing stakeholders that developing an ontology is the highest priority was the biggest barrier to implementing the solution.

ENABLERS

Amgen has a mature data science platform. This maturity enabled our project to focus on increasing the granularity of available data rather than the typical data collection and access issues found in most corporations.

ACTIONS

The most important action that we took was engaging the end-user to understand the challenges that reliability engineering teams face and what solutions they believe would have the greatest impact on the way they work.

INNOVATION

Following a hybrid approach using rules- and model-based text extraction has enabled us to immediately add value while building a robust, automated pipeline for training our model-based approaches.

IMPROVEMENT

Transforming an unstructured dataset to a structured dataset. The structured dataset enables the development of analytics for management and reliability engineering teams.

BEST PRACTICES

Begin by developing and understanding an ontology for your dataset. Begin with a rules-based approach to develop a baseline and quickly demonstrate value. Focus on creating a tight feedback loop with your subject matter experts to enable efficient data labeling/re-labeling for your model-based approach.

OTHER APPLICATIONS

This approach can be applied to any information-rich, free-text dataset.

Production | Automobile manufacturing | Improved process performance | Discrete / Continuous

Assessing Bottlenecks and Automation

BUSINESS PROBLEM

In manufacturing, it is vital to identify current or potential bottlenecks and create plans to either eliminate or mitigate them. There are a multitude of ways to assess a system and identify the bottleneck: visual inspection, production data, and anecdotal evidence, past experience, to name a few. Most strategies are a blend of methods with past experience and anecdotal evidence comprising the majority of the approach. The reliance on past experience instead of data leads to discrepancies between assessors.

APPROACH

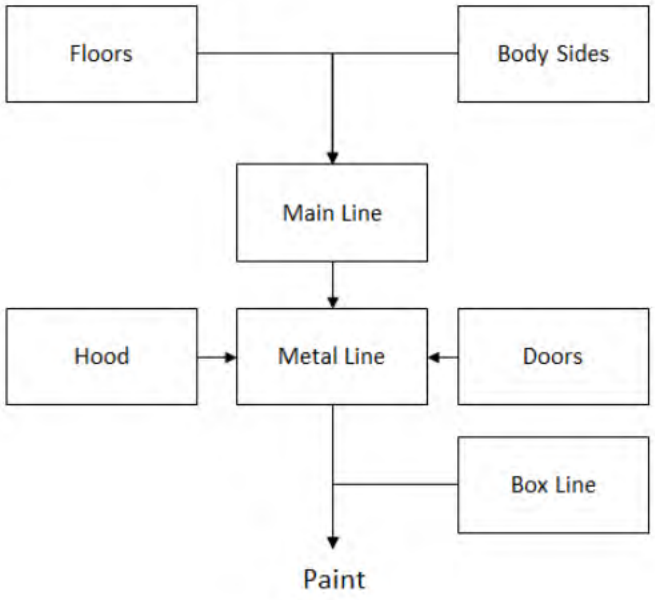
Using data and the institutional knowledge of the plant, I will develop a standardized processes to analyze and identify system bottlenecks and intra-cell inefficiencies, so that they may be removed or their effects mitigated.

DATA SOURCES

Cycle times of the robots are reported to a centralized database which can be confirmed with a stopwatch, vehicle build order database

Data Types and Format

Excel, histograms, probability density graphs



Author: Darron Sandifer

IMPACT

The solution will provide a standardized process guideline in which bottlenecks can be uniformly evaluated and give concrete steps to alleviate their effect on the system.

DRIVERS	The demand for cars is increasing so the plant needs to increase its efficiency if it is to keep pace with demand without increasing expenditures.
BARRIERS	In well established companies, organizational inertia to include but not limited to existing procedures and institutional knowledge will inhibit the implementation of change.
ENABLERS	Finding champions within the established system who can endorse and promote the change are the key enabler to getting procedural change enacted.
ACTIONS	I conducted a case study using the framework I had created in order to prove its usefulness.
INNOVATION	The framework I propose is innovative because it builds upon existing continuous improvement frameworks while still remaining simple to use and implement.
IMPROVEMENT	Using the framework proposed I saved Nissan approximately $60,000 annually in overtime.
BEST PRACTICES	When instituting the framework, use the coarsest grain filter first and for most of the analysis until the proper problem is identified.
OTHER APPLICATIONS	This type of framework can be used for all business functions not just operations.

Logistics / Distribution | Retail | Network optimization | Network analysis

Network Optimization of a D2C Supply Chain

AMERICAN INDUSTRIAL PARTNERS

BUSINESS PROBLEM

DistroCo is a US distributor of hygiene products. Through high service, product expertise, and excellent customer retention, DistroCo has enjoyed three decades of consistent growth and is well-positioned amongst favorable market macro-trends. However, recent inflationary pressures have caused less-than-average profitability, prompting a renewed focus on cost optimization and pricing. DistroCo's largest cost line-item behind COGS is shipping expense. Current pricing strategy absorbs shipping rather than passing it on to the consumer directly. DistroCo has opportunity to reduce expense, transit times, and service through network optimization.

APPROACH

This approach will include (1) development of a future-state network design with shipping as the primary driver, (2) optimization of fulfillment expense including shipping, middle-mile freight, & rent, and (3) scenario analysis of future business segment growth and associated risk. Revenue drivers, such as charging for shipping, will be trialed to understand customer sensitivity to responsiveness.

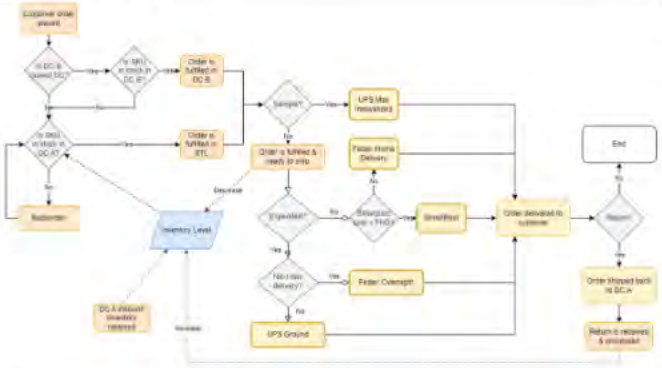
DATA SOURCES

DistroCo has plentiful data, including productivity, inventory, lead times, pricing, COGS, shipping, fulfillment, order, and other invoice data. Data is collected by DistroCo's home-grown ERP system and stored in an Oracle database. It can be queried via SQL. Additional data can be gathered through employee interviews, customer call "double jacking," and in-house time studies.

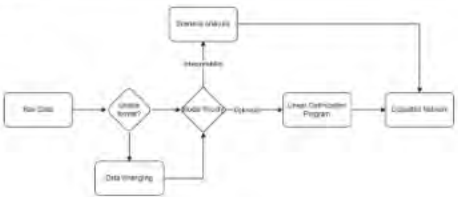
Data Types and Format

Data types include structured and time series order, invoice, and fulfillment data. Call center data includes audio and structured data.

Fulfillment Logic:



Model Logic:



Author: Julie Sarasua

IMPACT

This project paves the way for significant cost reduction, improved customer behavior, and better understanding of operational costs. Specifically, the impact of this project includes (1) a greater understanding of customer geographic dispersion relative to existing network layout, (2) tools for encouraging customers to consolidate their orders into fewer, more cost effective shipments, and (3) a roadmap for a lower cost of fulfillment, lowering total cost and improving net profits. The work in this project was performed in conjunction with key team stakeholders, who asked the right questions, facilitated engagement across the organization, and can champion implementation of the recommendation.

DRIVERS

The primary catalysts of the savings found in this work are (1) rising logistics prices exacerbating layout cost differences, (2) the rent/buy decision over-emphasizing the benefits of utilizing owned space, and (3) the vertical integration of DistroCo with a manufacturer consolidating its manufacturing location.

BARRIERS

Barriers to this project include (1) constraints on team time, (2) differing business priorities, and (3) uncertain pricing information, particularly as the cost to ship has and continues to change rapidly with inflation.

ENABLERS

(1) Entrepreneurial spirit. The company core team of founders have largely remained in today's leadership roles and retain the same sense of entrepreneurial spirit that grew the company over three decades. This entrepreneurial spirit is apparent in the team's openness to try new things and continuously improve. (2) Stakeholder support. The senior leadership team supported this project fully, enabling it as a priority.

ACTIONS

(1) The solution was developed in partnership with DistroCo team members. This incorporation into the planning process improved team alignment and led to a better solution. (2) The solution was presented as a range of alternatives, over which the senior leadership team could discuss tradeoffs not captured directly in the model. This improved buy-in and overall team understanding.

INNOVATION

(1) This solution shows similar results between a simple, simulation analysis and a more complex linear optimization program. The recommendation are to simplify the tool utilized to increase overall interpretability. (2) Order consolidation campaign shows meaningful reduction in fulfillment cost by simply fulfilling fewer individual boxes. Essentially, spend less by shipping less.

IMPROVEMENT

(1) Network optimization solution provides roadmap to a 5% reduction in total scoped cost with minimal impact to existing operations. (2) Order consolidation testing shows 60-70% customer acceptance rate to consolidating orders (lowering total shipping cost).

BEST PRACTICES

(1) Over-communicate the problem statement and problem-solving technique to ensure alignment. (2) Understand your data through visualization and discussion with local experts. (3) Simplify the problem and solution as much as possible. Emphasize interpretability to improve stakeholder involvement and buy-in. (4) Think outside the box.

OTHER APPLICATIONS

(1) Small data problems eligible for simulation solution rather than optimization. (2) Small to medium sized distributors attempting network optimization. (3) Scenario analysis testing.

Supply Chain Optimization

BUSINESS PROBLEM

As the company scales, adds customer orders, and increases the build rate of new automated warehouses, it is important that construction materials and technological equipment arrive to the site in a sequenced and timely manner. These build sites share space with active client Distribution Centers, therefore space is limited and delivery processes that are optimized across the entire supply chain are imperative. This project focuses on developing a strategy for upstream inventory needed to prepare the supply chain for new customer orders and deliveries within a competitive time frame.

APPROACH

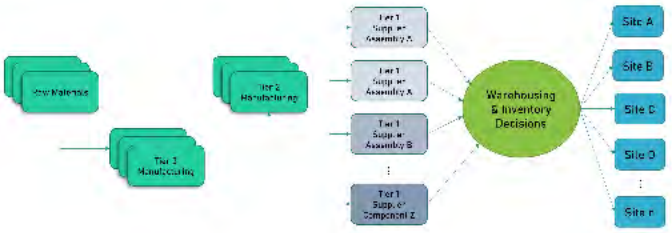
The relative qualitative and quantitative benefits of different inventory and warehousing options were assessed by building a cost model, visiting a site, and learning from key stakeholders. Next, optimal inventory levels and locations were assessed based on lead-time data gathered. Finally, a framework for adding in variability was recommended.

DATA SOURCES

Site material information, schedule, stakeholder experience, operational constraints, supplier cost and lead time data.

Data Types and Format

Supplier cost and lead time data in the form of spreadsheets. Stakeholder inputs in the form of verbal discussions.



Author: Lisa Schleuter

IMPACT

Stocking Tier-2 inventory at varying levels, as recommended, results in 65% lower inventory costs than the baseline strategy of stocking Finished Goods to a set amount of inventory. The framework recommended can be a common starting point for many stakeholders in setting their inventory plan. Preventing construction delays at the sites, and speeding up overall construction flow has a large financial impact on annual costs and support good customer relations.

DRIVERS

This company is executing on projects that are somewhere between a "project-based" approach and a typical manufacturing line approach. This unique project type in addition to large projected growth called for a fitting inventory strategy.

BARRIERS

Delayed supplier communications slowed the progress of coming to a conclusion. The company is outsourcing some of the operational work, meaning a greater number of stakeholder involvement.

ENABLERS

Learning about tangential work going on in other groups helped me form a more complete picture of what was needed and how I could complement that to be most helpful for the company.

ACTIONS

I worked with an executive project champion to ensure the right stakeholders had access to the project findings and recommendations. Taking on additional projects for stakeholders helped build relationships for learning more about how my project was related and could be helpful to the team.

INNOVATION

The project explored how to apply some common inventory analysis methods to a situation where there is little historical data, and the project type is between "project-based" and assembly line.

IMPROVEMENT

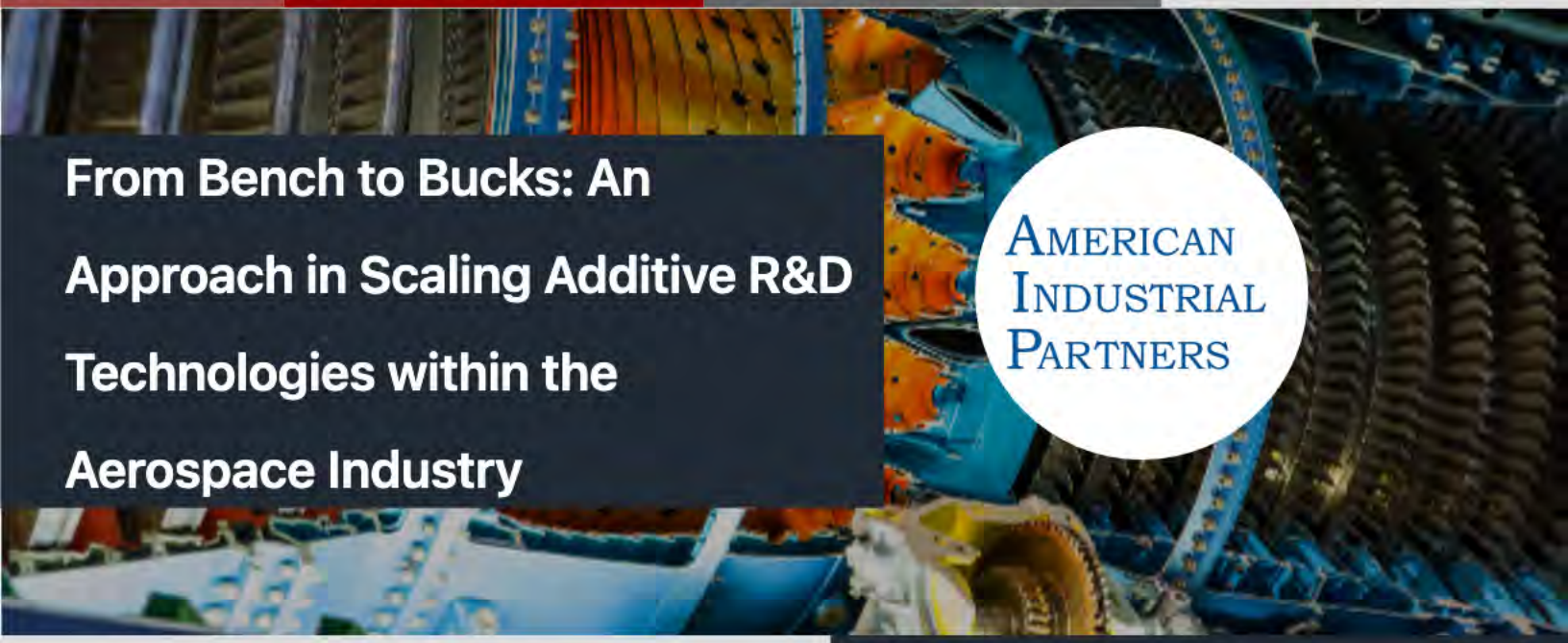
The recommended inventory strategy could lower inventory costs by up to 65%. The framework for applying information from future data received would also make their strategy more stable.

BEST PRACTICES

Inventory can be broken down into types and assessed based on what type of problem it is trying to provide buffer for (i.e. long lead time vs high risk item). Finding the right level to assess inventory is key for a highly complex product involving this many parts.

OTHER APPLICATIONS

This could be applied to other newer companies that have little order history, are going through supplier changes or have high growth and are working on relatively large projects.



From Bench to Bucks: An Approach in Scaling Additive R&D Technologies within the Aerospace Industry

American Industrial Partners

BUSINESS PROBLEM

Scaling technology-focused companies is a unique challenge, as taking cutting-edge technology from the lab to consumer markets often requires significant R&D work in parallel with all the typical challenges that any start-up faces. This thesis explores a new scaling framework (the "HHOQ Scaling Framework") through the lens of Wingate, a technology-centered company in additive manufacturing focusing on material development and printing of high-temperature metals. Wingate had notably strong customer relationships and a technically superior product to competitors, and is facing the challenge of rapidly scaling operations to meet customer demand.

APPROACH

The scaling framework is centered on a tool called the House of Quality (HOQ), which is designed to help prioritized design features of consumer products. By defining a Holistic House of Quality (HHOQ) that includes company-wide capabilities and auxiliary functions, and applying HHOQs to company growth, the research explores whether HHOQs can help guide scaling decisions for companies.

DATA SOURCES

Historical data sources at Wingate are slim. Offline excel files show customer backlog and quoting estimates. A Quickbooks account that details past invoicing, although it has already been confirmed that invoicing cannot be reliably tied to production. Data will need to be gathered through activity value stream mapping, interviews, and creating processes to begin collecting information on KPIs.

Data Types and Format

Data is contained in offline and online excel spreadsheets, and the web-based Quickbooks portal. Many documents are located in a common shared folder drive for the company.

Author: Allison Smedberg

IMPACT

Successful implementation of the scaling framework could lead to massive growth of Wingate in areas like operations, customer sales, facilities upgrades, and other areas. This scaling has the potential to increase revenues from ~$2M to ~$8M over the next 5 years, and provide exceptional service to customers to help them achieve their goals in aerospace and other industries.

DRIVERS

Additive manufacturing, especially within aerospace, is a rapidly growing industry with healthy customer demand. This ripe industry gives Wingate high growth potential to grow their top line revenue, and therefore high priority to invest money, resources, and time into their growth. Since the potential returns were high, it meant leadership support was there for the project.

BARRIERS

Primary barriers for this project included limited historical data sources, limited personnel headcount at the start-up to implement processes or data collection, and over the next 5 years, and provide the short timeframe for the research.

ENABLERS

The small organization allowed new processes to be implemented quickly and then adjusted with feedback. Leadership was open-minded and supportive of changes, and the rapid growth of the company meant that additional operations resources and changes to improve efficiency were welcomed.

ACTIONS

To implement this solution, I followed the HHOQ scaling framework: I performed a current state assessment (value-stream mapping) on the company's operations, interviewed customers to establish short-term and long-term HHOQs, identified and prioritized changes we wanted to make, and then implemented these changes at the company to see how they would impact operations.

INNOVATION

This research presents a new tool called the Holistic House Of Quality(HHOQ), and a new scaling framework utilizing this tool called the HHOQ Scaling Framework. The HHOQ builds off of the already-known House of Quality used in industry, and expands it to consider decisions and trade-offs at a company level to best serve customer needs.

IMPROVEMENT

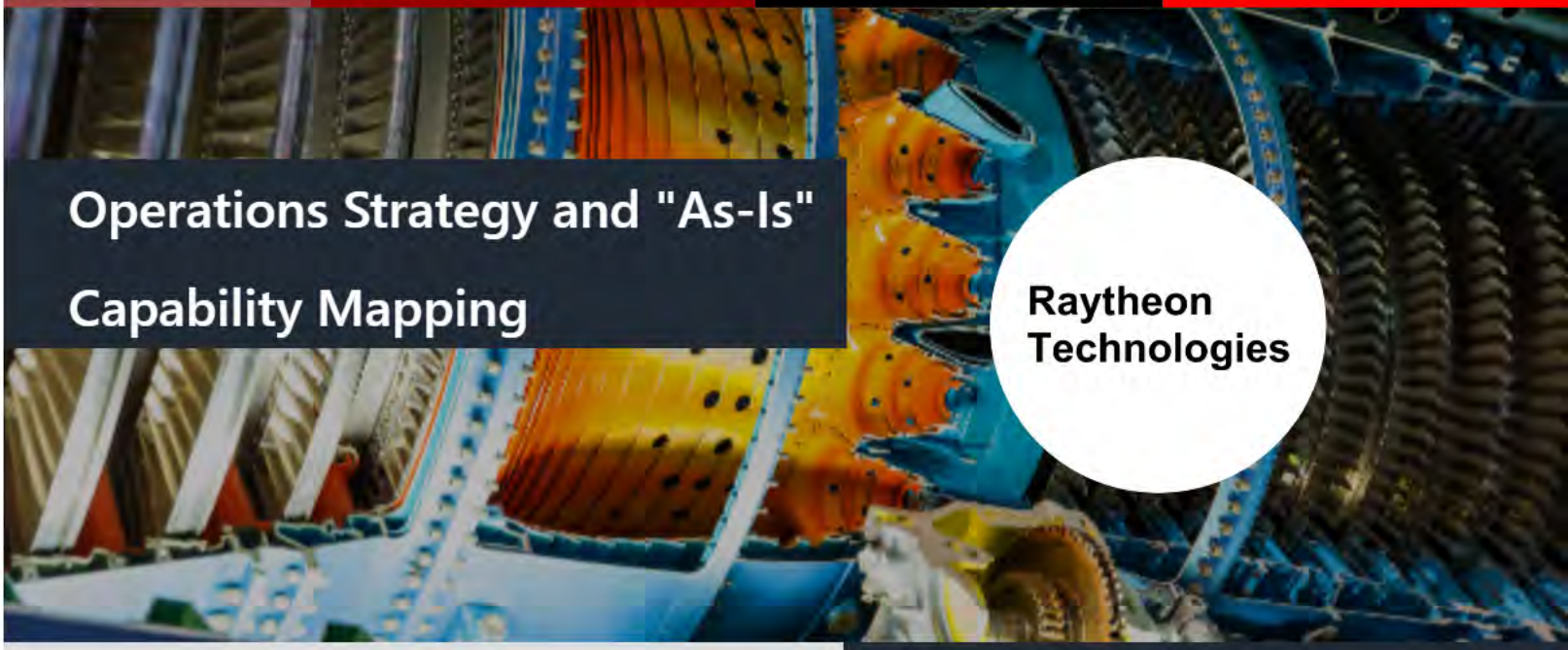
During the timeframe of the research, Wingate grew headcount from 4 employees to 10 employees, reduced overdue customer backlog by 46% and increased on-time delivery by 15%. The HHOQ framework proved useful in providing a structured way to assess scaling efforts in relation to customer needs, and successfully painted a picture of what other auxiliary functions would be important besides the success of the technology itself.

BEST PRACTICES

Best practices include getting management buy-in for the framework, performing in-depth customer interviews to inform the HHOQ tools, thinking through interventions at a systems level to decide when and how to implement them, and focusing on institutionalizing successful interventions.

OTHER APPLICATIONS

This thesis is anticipated to be a starting point for more wide-spread consideration of HHOQs as a tool in scaling decisions, including the effectiveness of the framework over longer time horizons and across various industries.



Operations Strategy and "As-Is" Capability Mapping

Raytheon Technologies

BUSINESS PROBLEM

Raytheon Missiles and Defense (RMD) is a business unit of Raytheon Technologies which was formed by the 2020 merger between United Technologies and Raytheon. RMD is organized, in part, into several make centers which host and manage the production capabilities of the organization. Products produced at these make centers range from microelectronic components to fully integrated exoatmospheric missiles. In light of its product line diversity and Raytheon's post-merger synergies, this research sought to develop a methodology by which RMD could identify its core and non-core manufacturing capabilities and technologies.

APPROACH

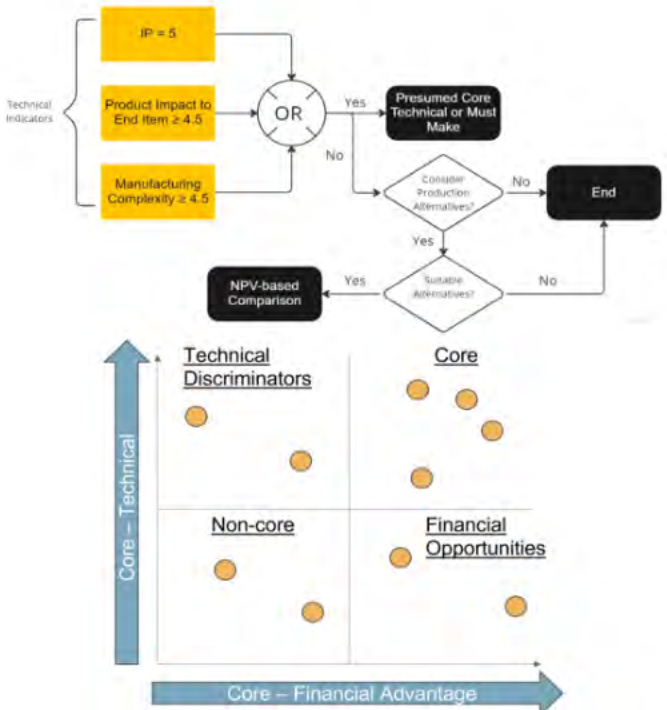
Two methods were developed. The first was an implementation of a Raytheon-developed framework in which scores were assigned to five technical and five financial metrics. Metrics were scored via a combination of Delphi surveys and business system data. The second was an author-developed alternative framework which placed primacy on technical optionality and net present value.

DATA SOURCES

Data was available from enterprise resource planner databases, production capacity models, financial forecasts, surveys, and interviews.

Data Types and Format

Data was a mix of financial data (e.g. program financial forecasts), production data (e.g. production timelines and costs), questionnaire scores, and interview transcripts.



Author: Thomas Ryan Stuart

IMPACT

The resulting frameworks can be leveraged by RMD to (1) rationalize capital investment choices, (2) identify high priority operational capabilities, and (3) identify opportunities to add operational flexibility. This will allow the business to better allocate its resources over the long-term. Importantly, a well-developed methodology will drive consistency across the RMD enterprise and offers a standardized schema to identify technical opportunities. The solution provided a way to measure the five technical metrics (product impact to end item, future demand, manufacturing complexity, sourcing alternatives, and intellectual property) and the five financial metrics (operations labor cost, operations labor cost variability, capital invested, manufacturing utilization, and quality). The alternative framework compressed the technical metrics (as shown in the image on page one) and reduced the financial metric to a single measure—net present value. The results from a pilot study indicate that both frameworks identify "core" and "non-core" technologies in line with expert expectations. In addition, the analysis shows that greater objectivity, less influenced by confounding variables (e.g. what level of the system a particular module resides at), can be driven by the alternative framework. This is attributable to the fact that it makes financial comparisons solely based upon a net present value measure rather than a composition of various proxies of future cash flows.

DRIVERS

The heterogeneity of the products manufactured by RMD was a key driver of the developed methods. The methods had to be extensible to a diverse set of products and account for the fact that manufactured products lie at the lowest level of modularity (e.g. microelectronic components) and fully integrated systems (e.g. integrated radars and missiles).

BARRIERS

Key barriers included removing noise from data and inferring some sparsity in the data set. This was a highly manual process of data refinement.

ENABLERS

The people at Raytheon are outstanding and very supportive of one another. If I had a question or needed assistance, I could easily secure time with the right points of contact and subject-matter experts. A commitment to teamwork struck me as one of the company's greatest assets.

ACTIONS

I performed a pilot study with both frameworks and reported out on the results to the leadership team. Moreover, I endeavored to document the process for the personnel taking over responsibility.

INNOVATION

The solution helps rationalize both frameworks, in particular the alternative framework, based on the economic value of system modularity. Additionally, the frameworks utilize Delphi surveys to help drive objectivity on the scoring of metrics which cannot be directly measures, e.g. manufacturing complexity.

IMPROVEMENT

The solution provides RMD with two implementable methodologies to score manufacturing technologies. Both methodologies can help the company to identify its core capabilities.

BEST PRACTICES

They should start by understanding the competitive strategy of the company. From there, best practice would be to combine an assessment of core manufacturing capabilities with the company's technology roadmap. On a tactical level, it is very important for one to understand what business systems the company has and what types of data these systems can provide.

OTHER APPLICATIONS

The alternative framework could be applied to other firms in other industries whose competitive strategy relies substantially on having best-in-class technological capabilities.

Logistics / Distribution | Farm Equipment | Transportation optimization | Uni / Multi-Objective

Making More Miles: Automating Load Selection, Truck Dispatch, and Backhaul Activation in Outbound Logistics Operations

LFMcapital

BUSINESS PROBLEM

IronCraft has achieved explosive growth over the past several years. The company's backlog has increased substantially as demand exceeds both production and shipping capacity. Organically grown processes that were effective at small volumes are creating operational challenges and lost revenue as the operation's scale increases. Specifically, it uses several short-term heuristics and locally optimal policies that conflict with their greater business objectives. In order to recognize the revenue contained in its backlog and meet growth goals, IronCraft must double its shipping capacity and determine the best logistical strategies to magnify the benefit of any additional capacity created through optimization.

DATA SOURCES

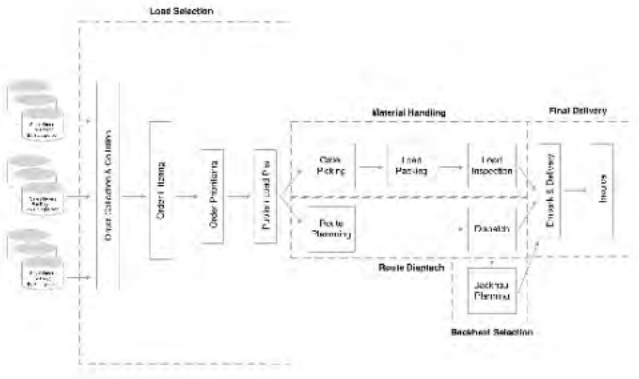
The data used in this investigation was collected manually from observing processes and digitizing manufacturing/logistics records. The methods developed in this investigation require minimal internal data collection and rely on large external data sources available through APIs like Google Maps and the Old Dominion Pricing Tool.

Data Types and Format

Time series, spreadsheets, API enabled graph databases.

APPROACH

The investigation began with preliminary analyses of operationally relevant departments; resulting in capacity, utilization, and cost benchmarks. Compelling opportunities were then identified in each relevant department, creating case studies to develop and test proposed automation/simulation methods. Each of these methods are compounding and contribute individually to solving the business problem



Author: Max Tanski

IMPACT

This project aims to deliver increased operational profitability, improved dealer/customer experiences to fuel further growth, and maximized shipping/logistics capacity without additional capital expenditure. Specifically, this will be accomplished through the development of a logistics software suite dashboard that will allow users to interact with logistics planning algorithms and view relevant inbound/outbound logistics metrics. Key modules of the dashboard will also be delivered as part of this project. These modules include an automated modality planner, a dispatch module, a trailer-load optimization module, and a production scheduling module. In addition to the software tools, the project will deliver a logistics data reporting pipeline and several operational logistic key performance indicators (KPIs). These deliverables will ensure that the software dashboard and its accompanying modules have the data required to function optimally while allowing the company's leadership access to the latest relevant information to certify that the logistic capability is being utilized appropriately. The project is expected to impact IronCraft by increasing its shipping capacity by 25% and improve its on-time delivery KPI to 60- 80%.

DRIVERS	The major driver of this project was the need to identify process improvements for the outbound logistics department that would allow it to scale to meet future growth goals and unlock synergies across the brand portfolio.
BARRIERS	Small sample sizes for available historical data. Multiple confounding variables. Hesitation from organization around automation and algorithmic implementation. No ongoing optimization or data efforts or projects at the company.
ENABLERS	This project was enabled by strong support from the partner company and its management. Additionally, the size of the company allowed the project to reach the appropriate depth and breadth within the company to access data and implement test cases.
ACTIONS	Spoke with subject matter experts about current process and potential improvements. Performed analysis to identify relevant KPIs and ground truth performance. Built software to implement algorithmic decision making, process automation, and process evaluation dashboards.
INNOVATION	The use of automation and optimization algorithms to aide employees as they make decisions about what orders to fulfill, how to fulfill them, and how profitable their decisions are in real time.
IMPROVEMENT	By applying algorithmic search methods, this project demonstrated how automating various capacity management strategies and tasks for employees could potentially save up to $873,396, generate an additional revenue of $1,193,618, and lead to higher employee and customer satisfaction in a small manufacturing operation.
BEST PRACTICES	Be sure to enlist a project champion from the management team, as a sense of urgency from management removes barriers and enables broader access to potentially useful and valuable resources.
OTHER APPLICATIONS	The final software platform would be applicable to any manufacturing organization that has to decide which orders to fulfill and on what modality within business

Supply chain planning and inventory management | Retail | Transportation optimization | Constrained / Unconstrained

Optimizing Apparel Pack Sizes Across Retailer's North America Network

BUSINESS PROBLEM

Manufacturing partners of major apparel retailers pack the same stock-keeping units (SKUs) in different sized cartons and different quantities per carton. This becomes suboptimal for the retailer's North American distribution center as they become capacity constrained from unnecessary repacking from inconsistent and historically unknown carton pack factors (CPF). Apparel CPF practices are currently not compatible with an enhanced regional network and will continue to drive up repack rates as direct-to-consumer business surpasses the previous wholesale network strategy.

APPROACH

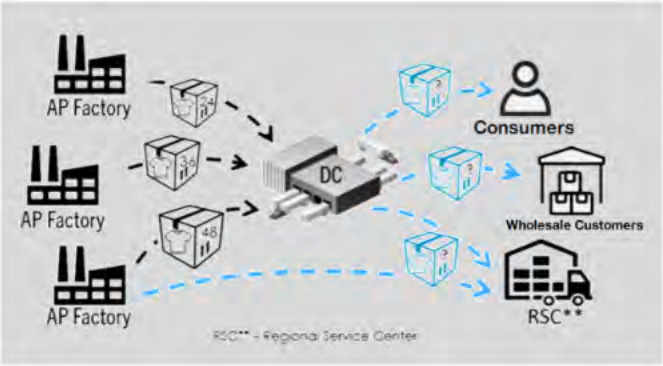
Understand how CPF would impact key supply chain metrics calculated per each order's line item. Iterate over all possible CPFs to calculate metrics including but not limited to: cartons received and shipped, repack and full case throughput, and processing costs. Metrics are then evaluated as a cost per unit to determine the optimal CPF per Gender-Product Classification combination.

DATA SOURCES

Historical and Forecasted Demand: Data is available to answer how many apparel units are ordered, will be ordered, and through which demand channels. Supply Chain Capacities and Transportation Costs: Understood how CPFs will modify the cost and capacity inputs at the distribution and transportation nodes.

Data Types and Format

All historical and forecasted demand exists in SQL databases. Cost and capacity metrics exist separately in Excel spreadsheets.



Author: Jason Teno

IMPACT

As sales orders trend lower due to an increase in e-commerce sales, the optimization model suggested decreasing pack sizes to accommodate these trends and decrease the variation in pack sizes across product classifications. Immediate implementation would result in a 13.2% reduction in repackaging costs. After implementation, communication with customers to match sales orders to pack sizes would result in a 39.2% reduction in repackaging costs. Added qualitative improvements include transportation savings with digital supply chain improvements, better resource allocation for digital orders, optimal internal transfers, and the ability to open cross-docking facilities.

DRIVERS

The apparel industry's shift to more direct-to-consumer sales at the wake of COVID-19 made this solution more relevant. Retailers are now more willing to move away from a traditional hub and spoke model to quickly cater to local consumers. Having an optimal pack size creates more efficiencies locally.

BARRIERS

Data availability was a difficult barrier to overcome. Specifically, incoming data to the distribution centers on pack size quantities was not historically recorded.

ENABLERS

Willing stakeholders from first, middle, and last mile logistics enabled this product. Additionally, teammates from global and local roles advocated for the benefits of this project.

ACTIONS

The data was formulated through Python to create the mixed integer program using Google's OR Tools and the SCIP solver. Once data was cleaned to create the model's inputs, the model itself took less than two minutes to solve the optimal solution. This optimization model was implemented into the data science team's array of products.

INNOVATION

Creating multiple, optimal pack sizes per gender and product classification is unique to the retail apparel industry. This solution was able to find many local optimums to minimize the overall network cost instead of focusing on one product classification independently.

IMPROVEMENT

The primary improvement is the standard pack size per unique gender and product classification. Further, making these standard pack sizes cost optimal drastically reduces the unnecessary repackaging costs that middle mile DCs undertake.

BEST PRACTICES

Communication across different stakeholders. Considering this project starts at third-party manufacturing networks and ends at independent retailers, communicating the solution's impact is critical for success. This innovation must help the network's overall cost and this needs to be communication clearly.

OTHER APPLICATIONS

A standard pack size to optimize middle mile logistics can be implemented across any regional distribution network.

Operations | Retail | Improved process performance | Bayesian

Automated Guided Vehicles for Material Flow in Fulfillment Centers

Amazon

BUSINESS PROBLEM

The scale at which Amazon operates makes automation needed in the fulfillment centers (FCs) to increase efficiency, better utilize labor and lower safety risks. Currently, automated guided vehicles (AGVs), portable robots that can transport materials, are not utilized in majority of FCs in the network. Other industries such as automotive, have thoroughly integrated AGVs in their processes to limit heavy material handling by operators and increase the safety of the manufacturing environment. Amazon seeks to integrate AGVs across the network to improve process and labor utilization, efficiency, and safety.

APPROACH

This project will use process flow analysis to identify the areas in which transport support associates, who move materials throughout the FC, are heavily utilized in the process. The analysis will then be used to determine the appropriate AGV technology that could be installed. Using discrete process simulation models, the AGV usage can be analyzed to determine the effect on process defects.

DATA SOURCES

Although Amazon has a plethora of data available, data specifically on manual transportation is limited because there are no rates associated with that part of the process. The researcher will utilize existing data for labor metrics which detail hours used for transport support for different areas of the FC process. The data on transportation waste mileage has to be manually collected at the FC.

Data Types and Format

The data is contained in SQL data bases that can be accessed programmatically or via Excel spreadsheets.

Author: Kaya Thomas Wilson

IMPACT

Without the installation of AGVs in the FCs, associates will have to continue manually transporting materials using pallet trucks and carts. Manual transportation increases human-PIT interactions which increases safety risk and adds more traffic in the facility. Manual travel time also adds additional labor costs. AGVs have the potential to significantly decrease manned travel, facility traffic and labor costs while improving material flow.

DRIVERS

The fulfillment and warehousing industry requires a lot of manual labor, technology integration is becoming essential in order to scale operations in a way that reduces the amount of manual work while still maintaining process efficiency.

BARRIERS

There are a lot of silos at the company that made it hard to track down past history/projects related to my work. There isn't a central team working on AGV integration across all of the FC network which made it difficult to find the right team members who have knowledge on related projects.

ENABLERS

The main enablers of the project were the associates and area managers who helped me understand the process and collect data for the research.

ACTIONS

I was not able to integrate the solution given the long timeline required for scoping, purchasing, training and integrating AGVs into the FCs.

INNOVATION

The innovation aspects of the solution are the ways in which the technology can be integrated into the process without requiring major changes to the process and making the processes simpler through the integration.

IMPROVEMENT

The simulation results indicate that the integration of AGVs in Inbound Stow process can increase individual throughput by 200-300 products per shift per associate and reduces total idle time. The results demonstrate the potential for AGVs to improve the productivity of FCs. The work concludes that AGVs can improve FC operations in the short and long term, with the potential for significant labor cost savings.

BEST PRACTICES

If someone was attempting to replicate the simulation in a real-world environment, the most important aspect would be obtaining buy-in from the associates on the floor to ensure they understand and believe the technology will help make their job easier. If they are not bought into the solution, there is a high likelihood the technology will not be successfully integrated.

OTHER APPLICATIONS

The solution can potentially utilized in other industries that have distribution and warehouse environments which are experiencing transportation waste in their processes.

Operations | Manufacturing | Improved process performance | Lean Manufacturing

Manufacturing Integration: Managing Throughput and Organizational Change

LFMcapital

BUSINESS PROBLEM

Rainier is working to maintain revenue targets and to improve EBITDA margin with the pandemic housing renovation boom coming to an end. The shade division has achieved high profitability and positive EBITDA over the past few years. However, with increased competition, capturing demand and reducing costs will be crucial to meeting financial goals. Rainier is acquiring Eclipse Shade, a competitor, and seeking opportunities to reduce its material, production, and overhead costs. Screen production will be moving exclusively to Statesville, NC and the production rate will need increase 100% to keep up with demand.

APPROACH

Through data analysis, I have concluded that standard color offerings, reduced custom color volume, and design improvements, will reduce the number of steps required in the process, and allow for an increased production rate in Statesville, NC. In addition, reorganization of the manufacturing floor and inventory storage optimization will further drive efficiencies.

DATA SOURCES

ERP system queries, team member provided excel sheets, and manufacturing observations.

Data Types and Format

ERP System, Excel, Time Series

Author: Jacob Tomasovic

IMPACT

The solution will reduce overall costs of screen production and increase unit throughput. Through SKU reduction and manufactucturing process improvement, the facility will be able to manage higher demand. Lean manufacturing principles guided the capacity and throughput analysis done at the plant to determine optimal machinery, headcount, and overall flow of product. Implementation of the recommendations provided in the study will allow for 100% increase in product output. The changes are still ongoing and the successful integration of the two companies will determine the overall success of the project.

DRIVERS

The company cared about the success of the project from the C-suite all the way to the factory floor where the changes were taking place. Each company had a stake in the successful integration of manufacturing lines to increase throughput and better meet demand of the customers.

BARRIERS

Multiple stakeholders in the project proved to be a large barrier to it moving quickly. Lofty timelines were set the at the beginning, yet differing stakeholder views led to slowdowns in decision making. In addition, the manufacturing site of the project was in North Carolina while the researcher was located in Washington. This made it more difficult to be involved in the day to day changes taking place on-site.

ENABLERS

The management team and each member of the Rainier team on the site in North Carolina helped enable my project. Their constant support and assistance throughout the process was key to the final product and analysis that resulted. Interviews with the plant manager helped the researcher realize what was possible within the constraints of the building and helped guide the final recommendation.

ACTIONS

Early time studies and plant walk throughs helped the researcher identify areas of opportunity. In addition, the gemba walks gave the researcher the opportunity to ask questions and begin formulating a plan of approach. Finally, gaining the trust of the team members was essential in building out floor plans and flow diagrams.

INNOVATION

For the outdoor manufacturer, innovation came with the complete change in the manufacturing approach. Eliminating a large portion of the process was novel but quickly led to results.

IMPROVEMENT

Once fully implemented, the throughput time of a unit on the manufacturing floor is expected to decrease by nearly 70 minutes. In addition, the cycle time per unit will reduce from 10 minutes to 7 minutes per unit.

BEST PRACTICES

Each process within the manufacturing line must be carefully assessed to identify areas of opportunity. Time studies as well as a capacity analysis on each individual process are key to understanding which levers to pull. Finally, visiting the factory floor and seeing the production flow is necessary to making an impact.

OTHER APPLICATIONS

This project may be applicable to companies experiencing rapid growth or manufacturing integrations after buy-outs. In addition, companies shifting manufacturing from multiple sites to a single site may find value in determining the best path forward from this research.

Operations | Industrial automation | Performance management | Rules-based

Predicting and Preventing Unsafe Events

BUSINESS PROBLEM

Accidents happen during the regular course of business operations, mistakes happen. When they do, lives can be lost, injuries borne, or losses incurred. Undergirding the story of Amgen, America's largest independent biotechnology company, is the need to produce drugs at scale to meet patients' needs every time. Although manufacturing is key, there are often undesirable incidents and injuries that interfere with the company's important mission. Seeking humanitarian excellence over economic benefits, Amgen wants to curb and ultimately reduce her unwanted events to zero!

APPROACH

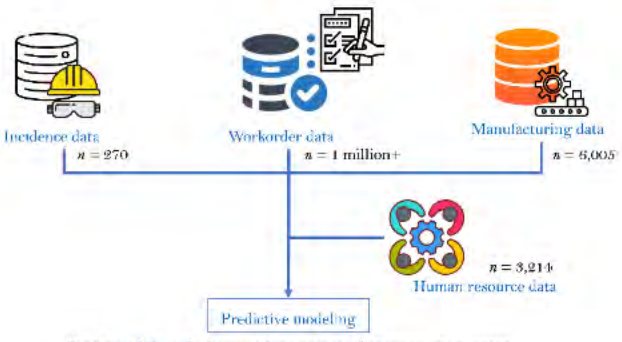
To facilitate implementation, a solution should have three characteristics. First, it should measure the presence of safety. Second, it should anticipate unsafe events. Third, it should avoid human bias common to systems where workers input key data. Under these constraints, a data-driven solution was the most plausible. We pooled plant, work order, and overtime data to predict unsafe records.

DATA SOURCES

There are four main sources: (1) the incidence, inspection and corrective/preventive action database which houses the entries of unsafe events; (2) the enterprise data historian which monitors machine variables on shop lines; (3) the work order database which accounts for repairs and fixes to various equipment material for our project's processes of interest; and (4) the worker overtime data.

Data Types and Format

Time series, videos, interviews, (in)formal chats, Excel documents, company's public data including some standard operating procedure documents, keynotes, and process maps.



Context: AML-01 Packaging where automated processes are common

Author: Onyinyechi Chiemela Ukaire

IMPACT

A data-driven tool that calls out unsafe events before they happen and endorses safe events while they happen will promote a safety culture less prone to chance. It also has far reaching consequences including improving staff and contractor health, advancing humanitarian causes, and ultimately yielding more productive worker days stemming from cutting down treatment costs and avoiding lost days due to injuries. While shy of a real-time, aspirational tracking of systemic safety, the proposed solution has three primary impacts. First, it affords a clear example of a context in which a top historical approach to industrial accident prevention, namely the H. W. Heinrich's safety triangle, falls short. Reducing no-injury accidents or minor injuries does not commensurately limit major injuries. Second, modeling for manufacturing variables alone —- whether machine data or work order data based on these machines —- does not yield strong predictive power for unsafe events. It is no brainer that machines are not necessarily the source of undesirable events at a company. Third, modeling for human factors notably improve the discernible ability of our predictive tool suggesting that human errors, however elusive, must be amply accounted for in such modeling efforts. We see a path to a data-driven predict and prevent safety culture.

DRIVERS

The type and quantity of data available allows room for more refined analysis by machine learning and artificial intelligence tools. There is also a text component of the data that affords opportunity for Natural Language Processing, although it has so far been under explored. Structured data already in numerical and/or categorical forms allow for ample pattern matching techniques.

BARRIERS

The unclear architecture of several internal data systems came across across disjoint at first. Later I realized that there was a data-science workbench where data flow was expedient. Gaining admin access, however, was a new pain point. I was worried about real-time aspirations, as my results could inform the wrong approaches to safety. Such a sad event may enable injury occurences.

ENABLERS

The company judiciously kept a historian record of their incidence data, which was informative for a time series analysis. The standard operating procedures were also well written and detailed enough that by surfing them, I could understand the scope of an evaluated resource.

ACTIONS

A mix of things: talking to business unit leaders to understand the problem; outlining a potential solution, scoping the solution as a project, and presenting my initial thoughts to the leadership team to check my thinking; and then experimenting by way of trial and error to see results and learn from mistakes.

INNOVATION

The underpinnings of what I will do will cut across industries, not just a biopharma like AMGen. Also, while I am working within the Environmental, Health and Safety System function under the Operations arm of the business, my work should inform the data strategy of the company. The new facility being built in Ohio will very likely employ some of the lessons from my project — an unexpected feat.

IMPROVEMENT

My solution brings hope. Amgen was struggling to find precursors for unsafe events at the company, and this project comes at an hour of need. The solution highlights a need to monitor human factors, and it re-centers the problem of safety on an under-explored subject: humans. What about humans should we begin to monitor? How do we assess worker fatigue? Answers to these kind of questions will help to resolve why accidents happen.

BEST PRACTICES

Understand your business context. We only tried this approach in biotechnology; however, we are eager to see benefits in other fields. To start, consider mapping your unwanted events into Heinrich's safety triangle to see if it also fails in your context; do not be surprised if it in fact fails. Next, run your predictive modeling on unwanted events as your independent variable, and human factors as your explanatory variables.

OTHER APPLICATIONS

The methodology can be used for other time-series analysis where data is sparse and where, nonetheless, predictive analysis will prove useful. Instances like disaster control like fire fighting, or construction and mining industries, are well positioned to adopt such a solution. My solution can be adapted for predictive maintenance to reduce downtime.

Product design / development / engineering | Healthcare / Pharmaceuticals | Product design and testing | Unsupervised Learning

Analysis of Respiratory Time Series Data for Breathing Discomfort Detection

ResMed

BUSINESS PROBLEM

Patients with obstructive sleep apnea (OSA) often cite discomfort as a reason for discontinuing continuous positive airway pressure (CPAP) therapy. Many healthcare providers do not have time or awareness to proactively intervene with adjustments that would improve therapy adherence. ResMed aims to understand which features in high-resolution respiratory data can be used to detect critical respiratory events such as breathing discomfort. The company also seeks to understand more effective ways to convey data insights to healthcare providers for better decision making.

APPROACH

Time-series clustering was applied to identify groups of patients who show similar patterns in their breathing characteristics. Clusters were inspected to understand the relationship between breathing signals and patient reports of discomfort on low pressures, and other variables of interest. Statistical tests were used to evaluated whether differences in variables across groups were significant.

DATA SOURCES

Several datasets are available and include the following: patient demographic information, device usage data, and high-resolution time series respiratory data. Data has previously been cleaned and de-identified and are in tables in ResMed's central database. Other data sources include patient reported data on air quality and quantity during the sleep onset period of therapy.

Data Types and Format

Patient data is stored in ResMed's database and tables are accessible via query. Qualitative feedback from patients was gathered via a survey and consolidated into summary reports.

Author: Shelby Unger

IMPACT

With the rise of cloud-connected CPAP devices, the sleep medicine industry is shifting towards products that offer a higher level of automation and personalization. ResMed is working to understand how it can leverage different sources of data to provide new products for health care providers and patients that are aligned with this trend. This project evaluates how effective high resolution respiratory data is for identifying patients who may be experiencing breathing discomfort or stuffiness at low pressure levels during the sleep onset period of therapy. The time series clustering approach enables the automatic segmentation of patients who have similar breathing patterns. By conducting statistical testing on variables relating to demographic characteristics, signal features, usage, and reporting of breathing discomfort, ResMed is able to assess which features are independent of the clustering and which are not. As a whole, this allows ResMed to understand which features in their data may be useful for predicting which patients are experiencing breathing discomfort and understand where they may need to invest in the collection of additional data to improve model accuracy.

DRIVERS

The advent of the cloud-connected CPAP machine has enabled ResMed to gather large amounts of data relating to therapy usage and health outcomes across different demographic groups. Today, the organization is investing heavily into new ways that it can leverage this information to improve patient outcomes. ResMed as a whole is focused on data-driven solutions for remote patient management, personalized treatment, and virtualized care.

BARRIERS

Industry regulations make it difficult to gather new types of data quickly. Self-reported data from patients also introduces challenges such as recall bias, which impacts model performance. Biological variability also means that respiratory events may present differently in each patient, making the model development cycle longer and more complex.

ENABLERS

ResMed has a data-driven strategy with a dedicated data science and artificial intelligence (DSAIL) team. The organization embraces data-driven solutions. It supports the data collection and experimentation necessary to generate data insights and productize machine learning.

ACTIONS

I collaborated closely with ResMed's DSAIL team and domain experts to understand the data the was available and its meaning in the context of the use case being explored. I then tested several modeling approaches, selected the one that yielded the best segmentation of patients, and assess the significance of differences in variables across the groups with statistical testing.

INNOVATION

This project applies a time-series clustering approach to categorize respiratory data gathered throughout the night by ResMed's AirSense 11 machines with the goal of understanding how different patterns may relate to patient reports of breathing discomfort at low pressure levels.

IMPROVEMENT

This analysis enabled ResMed to understand what features may be useful for identifying breathing discomfort in patients and understand limitations in their current data with regards to this application. Several recommendations were made for how ResMed might consider collecting additional data to enable accurate detection of breathing discomfort in the future.

BEST PRACTICES

Test several types of models and model parameters to confirm which suits your objective and data best. Work closely with subject matter experts throughout the process to confirm and understand results and insights.

OTHER APPLICATIONS

Clustering has been shown to be a useful tool for discovering patterns in labeled and unlabeled data sets for applications within the medical field and beyond. Time series clustering could be applied to other biological signals to understand different subgroups within the population, or to any other type of application with sequential data.

Supply chain planning and inventory management | Healthcare / Pharmaceuticals | Inventory management / control | Deterministic / Stochastic

Designing a scalable data science solution to improve forecasting and allocation of orthopedic sets

BUSINESS PROBLEM

Depuy Synthes has not launched a new spinal product in a number of years. In preparation for a new product launch, J&J teams want a better understanding of how this launch will impact inventory levels and key financial metrics such as gross profit. Key challenges to enabling a successful launch include appropriately estimating new product sales & COGS based on similar products, identifying and modeling launch scenarios, and successful phase out of legacy brands. Depuy Synthes aims to utilize this model to appropriate plan capacity and production for the new product over the next several years.

APPROACH

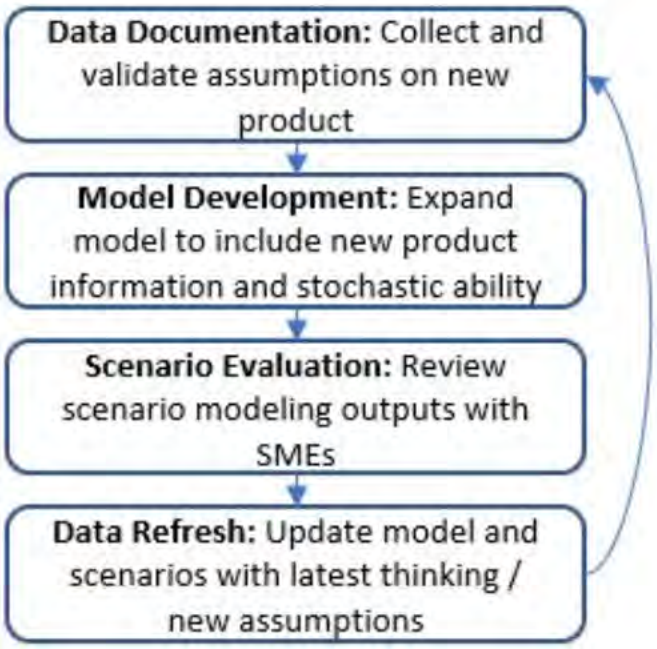
First, current new product assumptions (e.g., cannibalization) were thoroughly documented. Then the project will expanded the existing forecasting model to include impacts of the new product. The project then focused on creating a scenario model framework and prioritization of scenarios to analyze.

DATA SOURCES

Data within Depuy Synthes is available, however information often sits in different systems or at different granularities. Data sources will need to be combined to gain a full set of relevant inputs. The researcher will also augment the data via Excel spreadsheets using new product launch assumptions from experts on the team. These spreadsheets will be integrated with systems data through R.

Data Types and Format

Most of the data was contained in ERP systems and pulled from a database. However, there were also Excel spreadsheets used to map new product components to existing components.



Author: Alura Vincent

IMPACT

This work aims to support shifting the forecast of new products away from an Excel based modeling process into an easily repeatable approach that allows for testing of various launch scenarios. The baseline model provided the team with a single source of truth for assumptions in modeling the new implant. A sensitivity analysis provided the team with an understanding of the most critical drivers of gross profitability for this product. The scenario framework provided a structured way for the team to identify and prioritize scenarios in future uses, and is a strong starting point to expand scenario modeling for long-term forecasting outside of Spine products.

DRIVERS

A major driver of the project was the need to proactively plan against the uncertainty that is inherent in launching new products. There is a need to test various launch scenarios to understand the impacts across other Spine products to start working across teams and with suppliers to ensure success of the new product launch.

BARRIERS

There were updates to assumptions about pricing and cost that were continually made as development of the new product advanced. Another barrier was the time zone different between teams, making quick feedback or answers sometimes take longer than if the team was co-located.

ENABLERS

This project was enabled by the strong support at J&J - especially across the analytics and supply chain teams. It was also enabled by the expert knowledge of the spinal portfolio by the supply chain team. This was extremely critical to validate data assumptions for the new implant.

ACTIONS

One key action was identifying subject matter experts. The first was a supply chain team member who had expert knowledge of the broader spine portfolio who could help validate my assumptions in the baseline model. The second was a SME in the planning process to outline the steps and interconnected nature of the process across teams.

INNOVATION

A standardized framework that defines scenario types when launching a new implant as well as a sensitivity analysis allowing a comparison of changing both the cost and pricing of a product at the same time.

IMPROVEMENT

Identified which component in a spinal procedure impacts key financial metrics (e.g., gross profitability). Cost improvement opportunities with suppliers will focus on these components moving forward.

BEST PRACTICES

Develop a relationship with people who have worked at the company for several years and held multiple roles. They are key in providing context for the current project and also connecting you with others outside of your immediate team based on other job functions they have held.

OTHER APPLICATIONS

The scenario framework is generalizable beyond the spine products, although exact data needs for running scenarios outside of the spine team could change.

Supply chain planning and inventory management | Automobile manufacturing | Predictive Analytics | Decision Tree Regression

Enhancing Manufacturing Performance to Plan with Predictive Analytics

BUSINESS PROBLEM

Variances between actual production and original or revised manufacturing plans occur for several reasons. Sales may change their order, or disruption can force plans for later time periods to increase volume and catch-up. Further, capacity constraints can be inaccurate, unknown, or realized too late due to the complexity of process & product mix. Inaccuracy in manufacturing planning can lead to incorrect headcount, costly unscheduled overtime, and inaccurate purchasing from suppliers, which leads to excessive & obsolescent inventory, the bullwhip effect, and expedited orders.

APPROACH

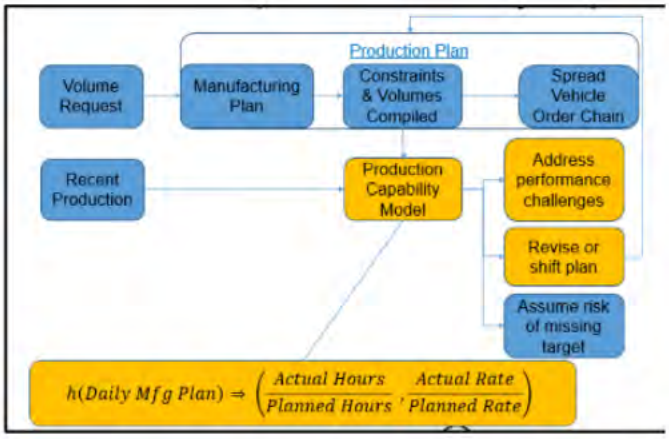
Monthly plans over time are compared to actual daily production. Empirical capacities are established based on best recent performance. Characteristics of the plan, such as model & trim mix, rate fluctuation, etc. are used to predict the actual daily vehicle output of each production line. An interpretable model predicts the output of future plans to correct or enable aggressiveness.

DATA SOURCES

Roughly 5 years of previous plans over multiple planning stages, and actual production, have been collected by processing & compiling saved data in excel/csv files, emails, and Nissan's data lake. Planning data has been cleaned to correct for inconsistency in human processes, and then supplemented with annual capacity estimates to calculate historical utilization levels.

Data Types and Format

Compiled data has been processed in a Jupyter Notebook and stored in csvs and pickled (pkl) data tables.



Author: Joshua Ian Weisberg

IMPACT

Manufacturing requires meticulous planning to coordinate tightly wound supply chain activities in the face of disruption. This is especially true for automotive OEMs, which produce complex products at high rates. These uncertainties lead to high error in plans, propagating changes to suppliers, other areas of the business, and future periods. Changes harm stability, efficiency, and thus profitability for all stakeholders. This study shows how predictive analytics can help. Results showed predictions provided Median Absolute Error (MdAE) improvements of 40%-60% over a 3 month lead time and 10%-40% over a 1 month lead time. Using these predictions to reduce error can improve stability such that better decisions can be made. Interpretation of the model can improve the factory's ability to meet demand. Benefactors include customers looking to purchase and receive their desired products, employees needing more consistency, and suppliers aiming to maintain a healthy business. The Covid-19 pandemic wreaked havoc on supply chains, and brought unprecedented strains on supplier relationships. Improving planning accuracy can increase robustness of operations for future major disruptions. While no plan would have foreseen the consequences of the pandemic, improved planning methods which better incorporate the capabilities of the plant can ensure that volatility is caused only by external factors, while machine learning models properly capture the impacts of controllable factors.

DRIVERS

The urgency of this project is driven by the volatility due to the pandemic. With an increase in supply disruptions, notably semi-conductor chips, the production plan accuracy has been lower, and more biased. This has led to deteriorating supplier relationships, and a need for more stability. Although the machine learning will not predict the supply shocks, it can help Nissan manage the controllable factors of planning, to increase robustness.

BARRIERS

The largest barrier is data access, as before 2020 data was kept in excel spreadsheets, emails, and csv files. Several months were spent finding, cleaning, and compiling data for model training. In addition, the incentives of the manufacturing planning process make it challenging to decrease volume. This means that the model should be interpretable, and provide guidance to improving performance, rather than only decreasing planned volume.

ENABLERS

Nissan Information Systems infrastructure made python and R tools readily available, as well as a snowflake data system, though it did not contain data from before 2020. In addition, the Supply Chain analytics team was a critical source of feedback and ideas. Finally, domain knowledge from the Nissan Supply Chain & Operations colleagues was crucial to ensuring the model would train on key metrics of the production system.

ACTIONS

An application which provides an interface to the machine learning model was provided. The application takes a manufacturing plan as input, and returns calculated fields, and a predicted performance to plan for each day as output. It also displays several visualizations to aid in interpretation of the model. With this predicted performance to plan, the manufacturing plan can be adjusted to increase probability of success.

INNOVATION

Previous work has reduced instability in automotive manufacturing. Improvements have been made to forecasting, postponement of variety, inventory held at the OEM, and to the variety of products made. This project innovates by augmenting the information available to the process with a prediction of performance, such that the capability of the current system is better understood. Previously, only binary capacity rules were applied to planning.

IMPROVEMENT

The resulting improvement is a 40-60% reduction in Median Absolute Error (MdAE) from the 3-month-out planning process and a 10-40% reduction in MdAE from the plan submitted the month prior to production, based on a test set of unseen data. This reduction in error leads to a more accurate and stable production process, if the predictions of performance are adopted into the plan.

BEST PRACTICES

480+ features were developed to characterize the manufacturing plan and recent performance, including empirical capacity estimates. To select features, a categorical selection process was used in parallel with hyperparameter tuning. K-means was used for anomaly detection to remove Covid-19 supply shocks, which are likely to confuse the models of other projects as well. Finally, R-shiny was used to deploy python-built models for a quick MVP.

OTHER APPLICATIONS

The methods used in this work can be applied to the production of other products. Each process should be uniquely trained, but the concept of using machine learning to predict performance to plan, in order to either adjust plan or improve performance, can be applicable elsewhere.

MITLGO

LEADERS FOR GLOBAL OPERATIONS

Massachusetts Institute of Technology • Building E40-315 • 77 Massachusetts Avenue
Cambridge, MA 02139 • lgo@mit.edu • http://lgo.mit.edu


facebook.com/mitlgo


MIT Leaders for Global Operations (LGO)


@mitlgo


mit.lgo


MIT LGO


MIT LGO


Massachusetts Institute of Technology