Proactive and Automated Control Kickoff

Guest Wi-Fi Instructions

1) Connect to USCGuest
2) Open a browser and head to wifi.sc.edu
3) Fill out form with email and phone number.

Wifi.sc.edu/guest/USCGuest_Cisco.php

McNair Aerospace Center
College of Engineering and Computing

Proactive and Automated Control for BMW

REMARKS FROM BMW

GENERAL INTRODUCTION

Overview

McNair Aerospace Center

Background

- Named in honor of a SC native and Challenger astronaut Ronald E. McNair, the 15,000 sq. ft. McNair Aerospace Center was founded in 2013 to meet the needs of a rapidly growing SC aerospace cluster.
- The McNair Center's mission is to grow South Carolina's knowledge-based economy and support industry through aerospace education, research leadership and industry advancement
- In 2018, the center expanded by another 20,000 sq. ft. to house other aerospace related activates in the College of Engineering and Computing.

Research Areas

Center for Predictive Maintenance	Additive Manufacturing	Drones & Unmanned Vehicles	Combustion
Industry 4.0, MSG, HUMS, CBM/CBM+, Component Testing	3D Metal Printing, 3D Composite Printing, Automated Fiber Placement	Vehicle Design, Communications, Indoor Experiments	Characterization, Fuel Formulation, Simulations

Advanced Composite Consortium (ACC)

Advanced Robotics for Manufacturing Institute

South Carolina

Fraunhofer USA

Demand for Aerospace in SC

THE TOTAL ECONOMIC IMPACT OF AEROSPACE IN SOUTH CAROLINA IS
$28.8 BILLION
Direct & Indirect

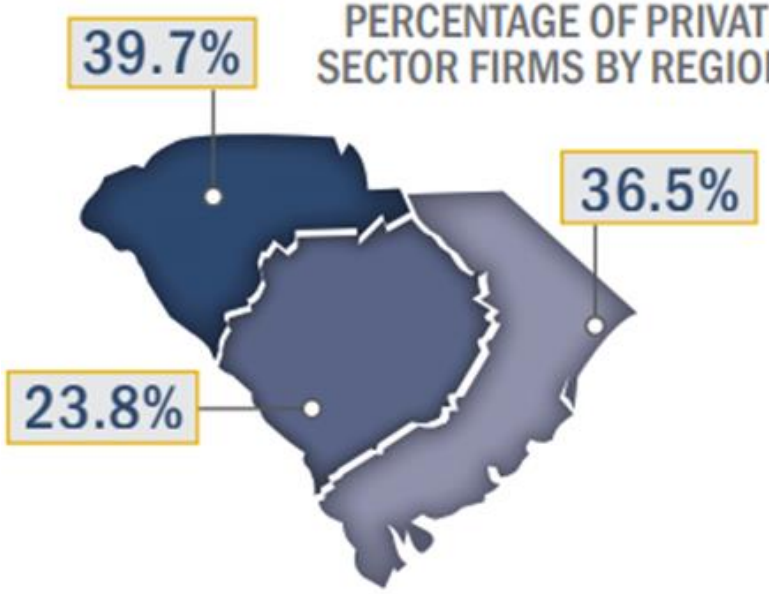
WITHIN THE LAST 10 YEARS, SC AERO CORE* AS A % OF THE TOTAL AERO CLUSTER HAS RISEN FROM 23.1% TO:

*Aero Core refers to non-military aerospace employees

FOR EVERY **1** AEROSPACE JOB,
1.7 ADDITIONAL JOBS ARE CREATED

SOUTH CAROLINA HAS
OVER 35
AERO-SPECIFIC EDUCATION & WORKFORCE TRAINING PROGRAMS

PERCENTAGE OF PRIVATE SECTOR FIRMS BY REGION



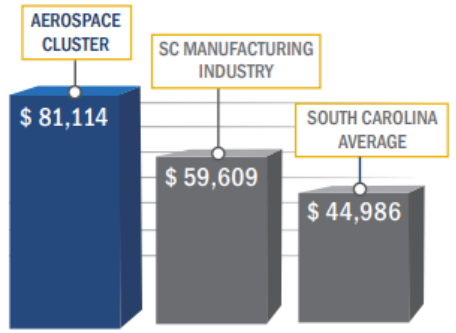
THE TOTAL NUMBER OF AEROSPACE EMPLOYEES IN 2019 WAS
136,244
Direct & Indirect

AEROSPACE CONTRIBUTES
$14.13 BILLION
TO SOUTH CAROLINA'S GROSS DOMESTIC PRODUCT.

AEROSPACE IS A MAJOR DRIVER OF SOUTH CAROLINA'S ECONOMY.
2009 - 2019

AEROSPACE EMPLOYMENT GROWTH
10.7%
SC EMPLOYMENT GROWTH
2.2%

ANNUAL TOTAL EMPLOYEE COMPENSATION
All wages & salaries



SOURCE: SOUTH CAROLINA COUNCIL ON COMPETITIVENESS

Project Overview

Challenge	Solution	Deliverables
• BMW assembly processes integrate thousands of parts, sourced from a wide variety of suppliers, located around the world • If these parts fail to arrive on time, costly delays and work stoppages follow • Requires monitoring that is done manually by highly experienced supply chain professionals • Tedious and expensive	• BMW seeks improved data-driven algorithms, systems and processes • Successful solutions will capture, analyze and exploit datasets to enable optimized and proactive materials control, optimize specialized human expertise, and reduce line stoppages due to missing parts	• AI material planner assistant and model for forecasting part shortages • This solution could be applied to other supply chain needs and could be scalable

Statement of Work

Phase 1: Data Collection and Development

- Data collection and analysis
- Develop models representing a wide range of data and interrelationships
- Identify subset of “easy to plan” parts, automate handling of these parts, suggest actions to take given a part’s status
- Evaluate path to full automation of low-risk parts

Phase 2: Proactive and Automated Reporting Integration

- Validate and enhance developed models and AI material planner
- Develop dashboards and reporting

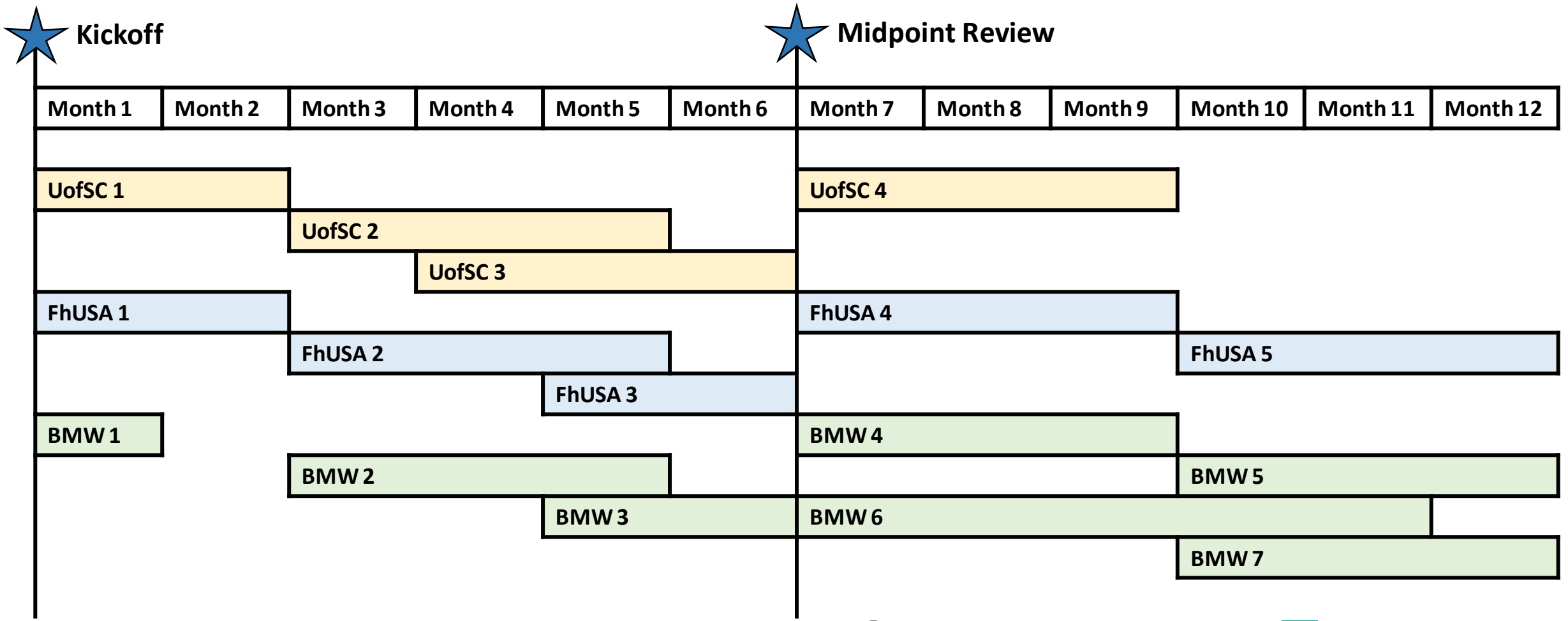
Tasks and Deliverables – Phase 1

Task #	Description	Deliverable	Time Range
BMW 1	Gather and provide the partners with historical BMW data	Historical BMW data delivered to partners	Months 0-1
UofSC 1	Exploration of historical BMW and extraneous data for forecasting part deliveries	Document: Key figures from historical data, rich/poor areas, supplier ranking	Months 0-2
FhUSA 1	Stakeholder interviews to identify how material planners approach problems	Prototype ER model, Presentation to stake holders	Months 0-2
UofSC 2	Data formatting and interrogation to identify relationships in data and capabilities of forecasting model	Key capabilities for part-forecasting model and prepared data for model creation	Months 2-5
BMW 2	Assist in AI material planner development	Active support and reviews	Months 2-5
FhUSA 2	Create AI Material Planner Assistant Prototype	Software: AI model material planner prototype. Workshops with partners to prepare integration	Months 2-5
UofSC 3	Develop parts forecasting model	Software: AI model prototyping forecasting capabilities	Months 4-6
FhUSA 3	AI assistant model validation	Tutorial on AI model, signals and patterns. Updated AI Model	Months 5-6
BMW 3	Perform model validation and testing	Active support and reviews	Months 5-6
Midterm Review – Demonstration of AI parts forecasting model and AI planning assistant prototypes			

Tasks and Deliverables – Phase 2

Task #	Description	Deliverable	Time Range
UofSC 4	Parts forecasting model validation	Software: Validated AI model	Months 7-9
FhUSA 4	Integrate forecasting model with AI Material Planner	AI Material planner framework with integrated AI forecasting model	Months 7-9
BMW 4	Systems of record integration		Months 7-9
FhUSA 5	AI Material Planner with alerting and human readable steps created	Workshops: status updates, alerting functionalities, human readable action steps. Software: Alerting functionality, human readable action steps. Software support: support BMW with integration of system at BMW. Correction calibration of system	Months 9-12
BMW 5	Integration of combined parts forecasting model and AI material planner		Months 9-12
BMW 6	Visualization, dashboard and reporting		Months 7-11
BMW 7	Feasibility study and testing	Document: Feasibility study report, final report	Months 10-12

Initial Timeline



BMW Team

Dr. Ken Kennedy

Manager of innovation and research lab.

Primary focus new technologies into BMW Group

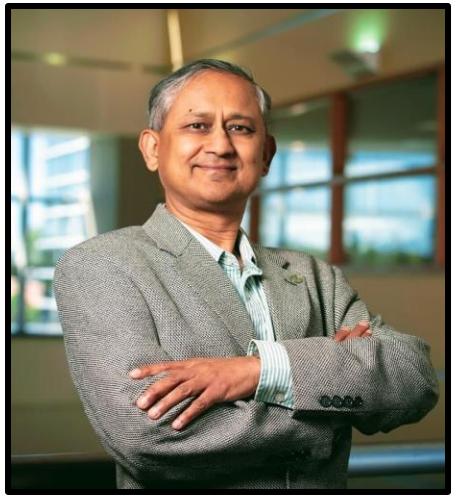
Allen Godsey

Manger of Innovation and Digitalization

Josh Abel

Innovation and Digitalization Team

Artificial Intelligence Institute of UofSC Team



Dr. Amit Sheth

Dr. Forest Agostinelli

Dr. Pankesh Patel

Ralph Gleaton

South Carolina

Fraunhofer USA

Fraunhofer USA Team

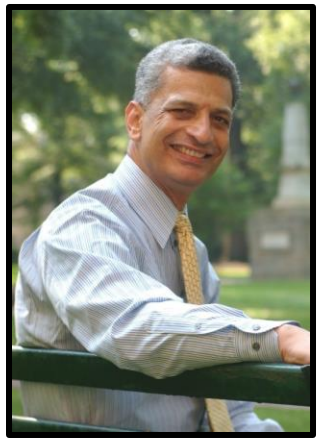
Dr. Jeno Szep

Michael Miller

Dr. Prahlad Menon

Brook Stacy

McNair Aerospace Center Team



Dr. Abdel-moez Bayoumi

Rhea Matthews

Evan Barnett

Andre Calderon

Clint Saidy

Rhiannon Bullard

Evan Meaney

Burton Rhodes

University of South Carolina

Fraunhofer USA

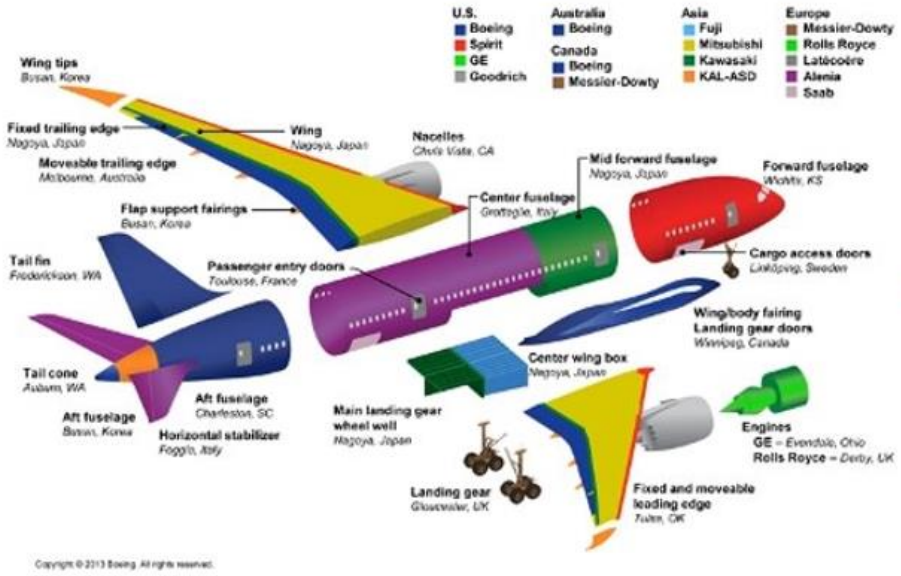
PROJECT INTRODUCTION

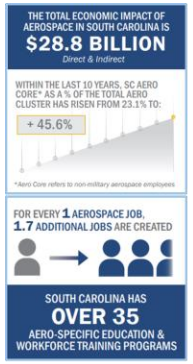
McNair Aerospace Center

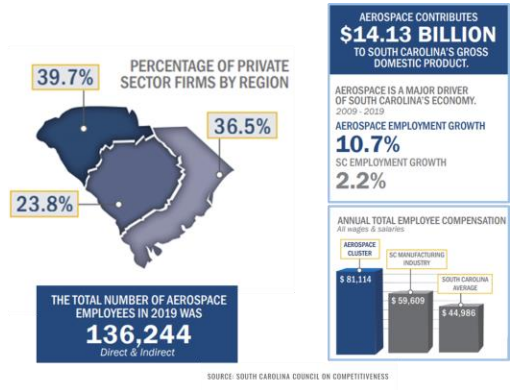
Tasks

Boeing SC Supply Chain – Introduction

Boeing SC sought to reduce the supply chain risk of the Boeing 787 along with its operating costs. This reduction was targeted by determining parts that are frequently late, and with relatively low dollar value.



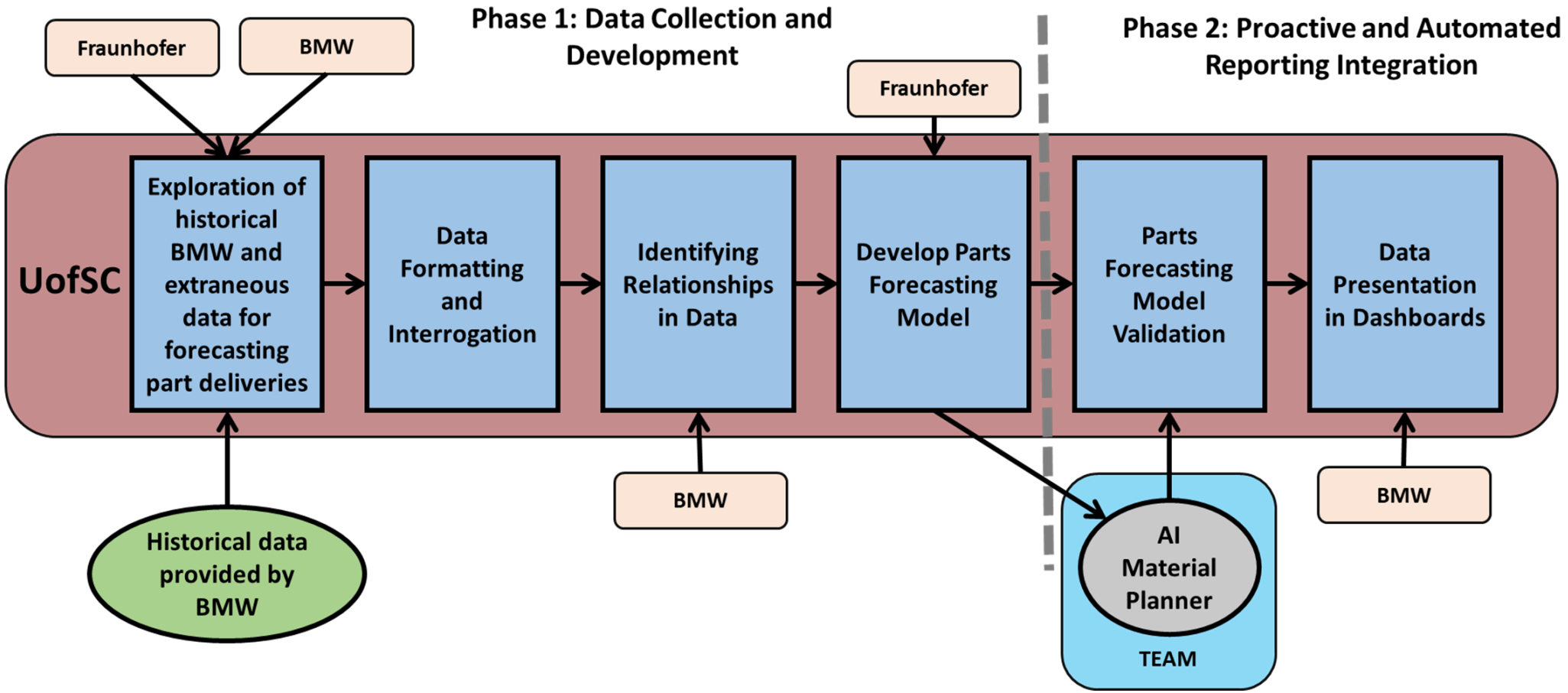




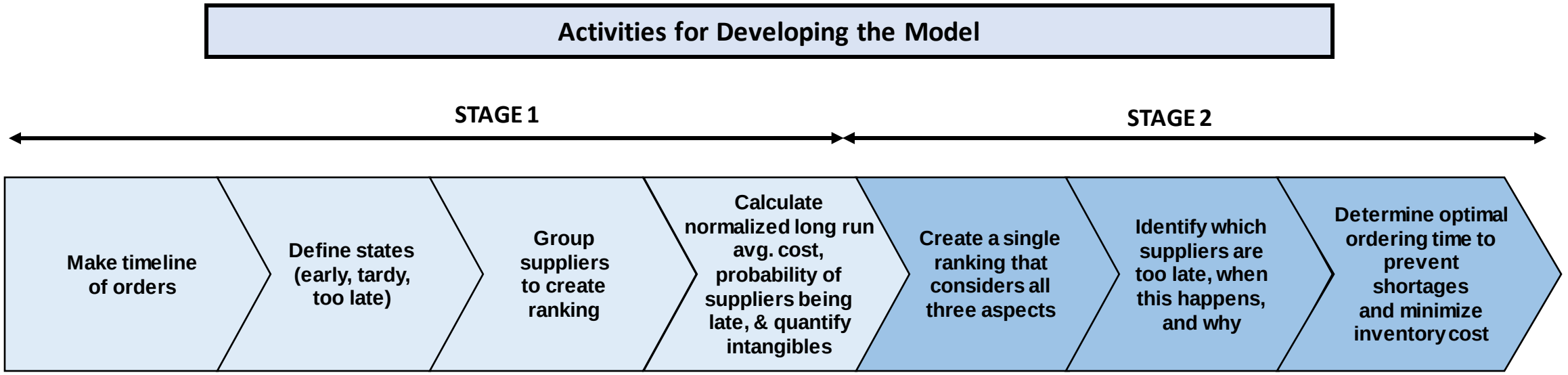
Boeing SC Supply Chain – Lessons Learned

- ***Delivery time*** and ***delivered quality*** are two main attributes of assessing vendor performance
- The ***Markov Chain Model*** allows us to calculate the ***Long Run Average Penalty Cost***, which is one way to assess and rank vendor performance
- Monetizing vendor performances allows a company to more critically evaluate vendors and make more informed financial decisions
- Other factors can also influence a decision to continue use of a vendor or not (international treaties, political influence, etc.)

UofSC Initial Roadmap



Parts Forecasting Model



Literature Research – Supplier Evaluation

- Two types of criteria: tangible (price, delivery time) and intangible (quality, flexibility, experience, etc.)
- Intangible criteria is ranked against each other (left) and consistency factor (right) is used to confirm subjective rankings

	qua	*flex*	*pot*	*fin*	*exp*
qua	1	1.5	1.2	1.4	1.3
flex	0.7	1	0.8	1.1	0.9
pot	0.9	1.2	1	1.4	1.2
fin	0.7	0.9	0.7	1	1.1
exp	0.8	1.1	0.9	0.9	1

Must be filled out

Reciprocals

$$cf = \left| 1 - \left[\frac{(A/C)}{(A/B) * (B/C)} \right] \right|$$

or

$$cf = \left| 1 - \left[\frac{(A/B) * (B/C)}{(A/C)} \right] \right|$$

Arkadiusz Kawa, Waldemar W. Koczkodaj, "Supplier Evaluation Process by Pairwise Comparisons", Mathematical Problems in Engineering, vol. 2015, Article ID 976742, 9 pages, 2015. https://doi.org/10.1155/2015/976742

Literature Research – Supplier Evaluation

- If cf is close to zero, weights (w_i) can be calculated and raw scores (x_i) assigned
- Weighted mean $\bar{x}$ (left) is used to quantify value of relevant intangible criteria which can be used to rank suppliers

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

Evaluation criterion	Weight	Sup. A		Sup. B		Sup. C		Sup. D	
	w_i	x_1	$w_1 * x_1$	x_2	$w_2 * x_2$	x_3	$w_3 * x_3$	x_4	$w_4 * x_4$
Quality of product or service	0.25	3	0.75	4	1	5	1.25	4	1
Organizational potential	0.18	2	0.36	4	0.72	5	0.9	5	0.9
Financial standing	0.22	3	0.66	4	0.88	3	0.66	3	0.66
Experience	0.17	4	0.68	4	0.68	4	0.68	5	0.85
Flexibility and adaptability	0.18	5	0.9	5	0.9	4	0.72	5	0.9
Total	1.00	—	3.35	—	4.18	—	4.21	—	4.31

Arkadiusz Kawa, Waldemar W. Koczkodaj, "Supplier Evaluation Process by Pairwise Comparisons", Mathematical Problems in Engineering, vol. 2015, Article ID 976742, 9 pages, 2015. https://doi.org/10.1155/2015/976742

Literature Research – Probability Theory

- Probability Theory is used when a large enough amount of historical data is available
- If there is not enough data, there is access to experience or experts' knowledge, other theories can be used to produce viable models

Object	Uncertainty Theory	Grey Systems Theory	Probability Theory	Fuzzy Math
Research Objects	Cognitive uncertainty	Small sample uncertainty	Large sample uncertainty	Cognitive uncertainty
Foundation	Uncertainty distribution	Information coverage	Probability distribution	Fuzzy sets
Requirement	Experience	Few data points	Large number of data points	Experts knowledge
Data Requirement	Uncertainty distribution	Any distribution	Probability distribution	Known membership
Objective	Laws of uncertainty	Laws of reality	Laws of statistics	Cognitive expression

Muhammad Saad Memon, et al., "Group multi-criteria supplier selection using combined grey systems theory and uncertainty theory", Expert Systems with Applications, Volume 42, Issue 21, 2015, Pages 7951-7959, ISSN 0957-4174, https://doi.org/10.1016/j.eswa.2015.06.018.

Literature Research – Methods and Models

Categorical Method

8 Step Method through that quantifies vendor performance through Critical, Objective, and Subjective Measures

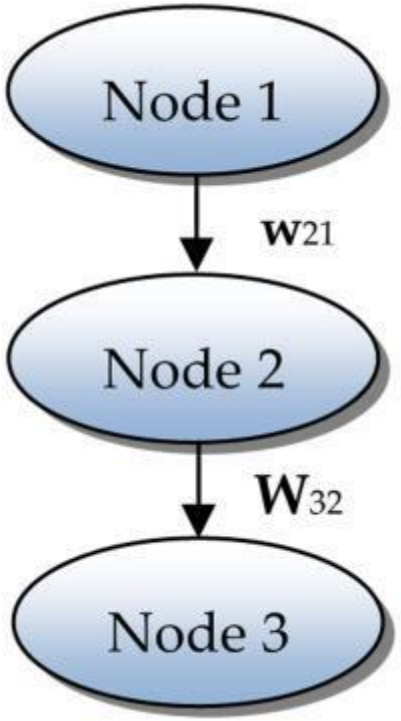
Step 8: Supplier performance measures are calculated.

- ***(SPM)=CFM(X×OFM+(1-X)×SFM)***
  - ***Where X is the relative importance of objective factor indecision making***
- ***Possibly allows for combination of several techniques***

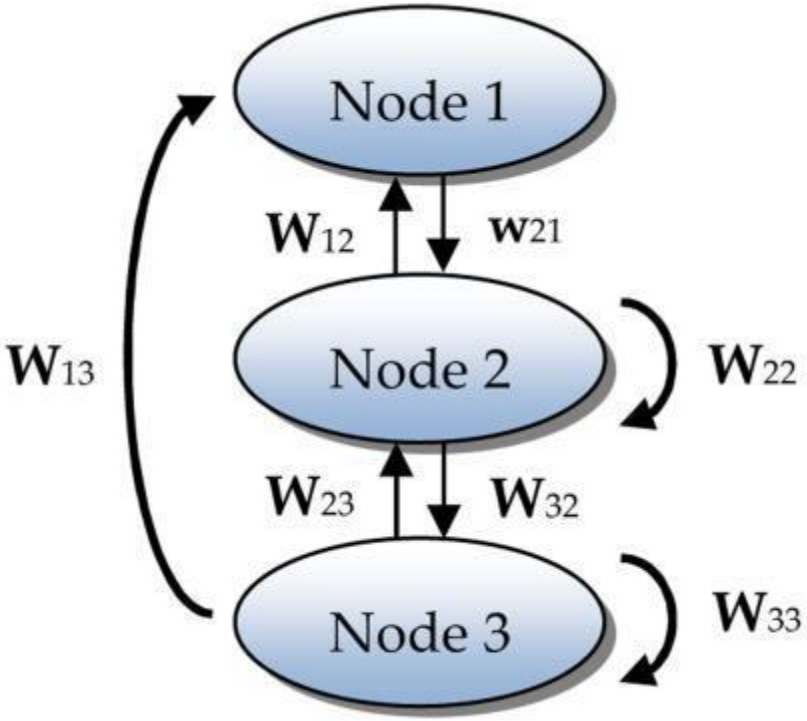
Literature Research – Methods and Models

Analytical Network Process (ANP)

Extension of AHP but replaces a hierarchical structure with a network structure.
Step 1: Model construction and problem structuring
Step 2: Pairwise comparisons matrices of interdependent component levels
Step 3: Supermatrix formation
Step 4: Analyze principles of logistics attributes and evaluate alternative evaluations



Analytical Hierarchy Process



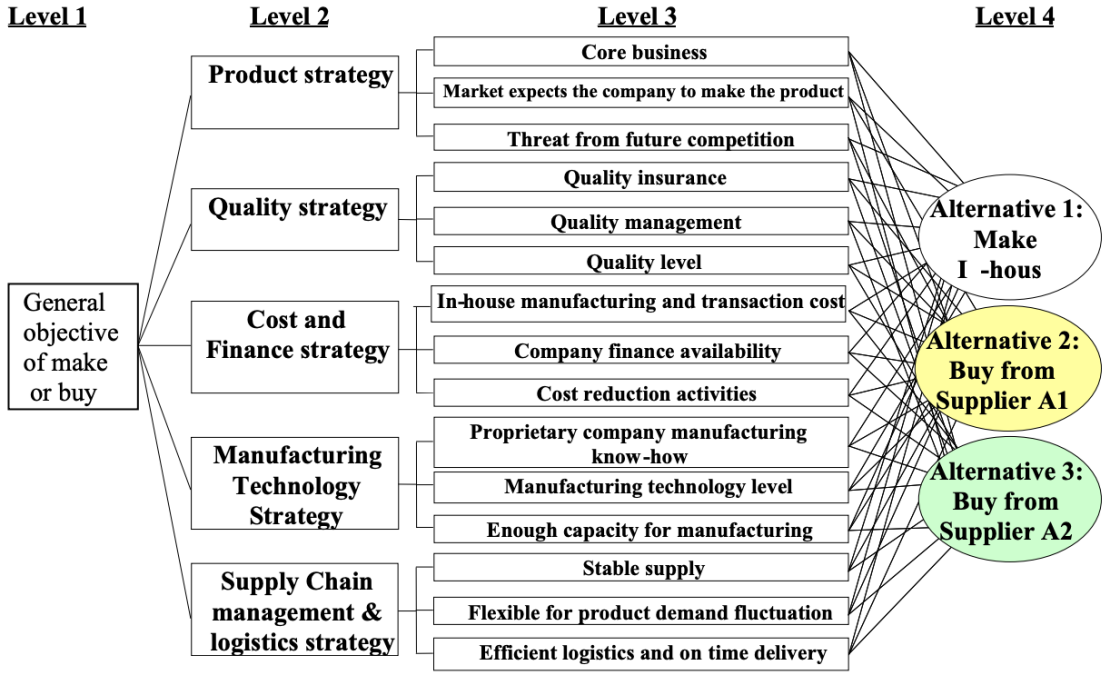
Analytical Network Process

Literature Research – Methods and Models

Make or Buy Model

Main Criteria:

- **Product strategy**
- **Quality strategy**
- **Cost and finance strategy**
- **Manufacturing technology strategy**
- **Supply chain management and logistics strategy**



PROJECT INTRODUCTION

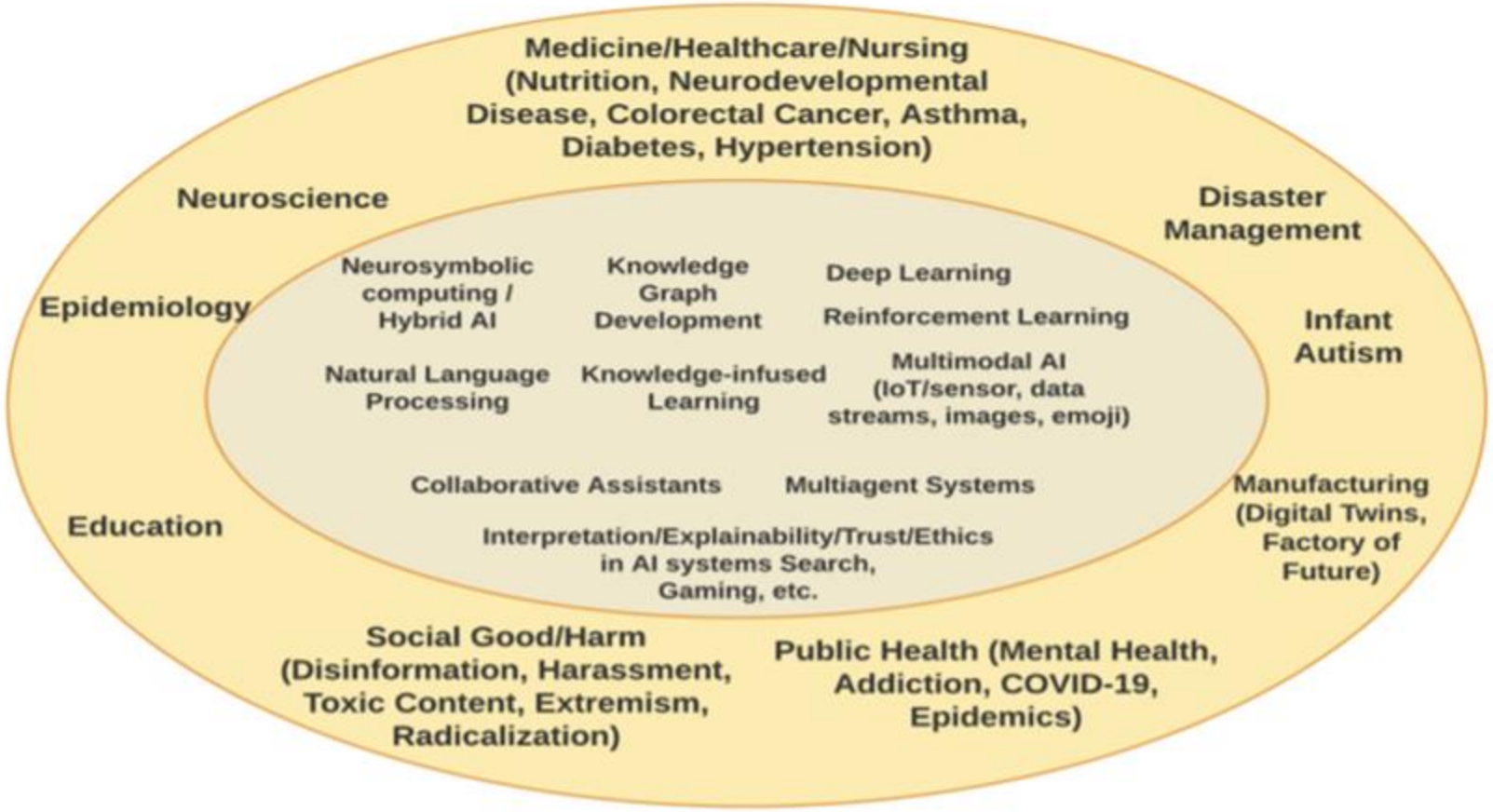
AI Institute

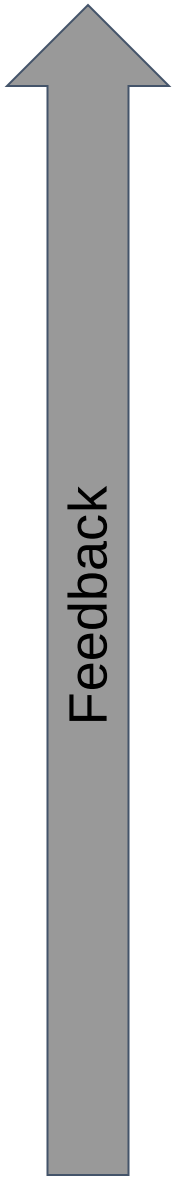
Tasks

Brief - AIISC (AI Institute of UofSC)

- First university-wide AI Inst in US SE
- Core research on AI topics such as deep learning, NLP, knowledge infused learning, neuro-symbolic and brain-inspired computing, collaborative & conversational agents
- Translational research with nearly all colleges at UofSC: clinical/dHealth, public health, epidemiology, pharma, nursing, disasters/epidemic, smart manufacturing, education
- More at: http://j.mp/AII0720

Core AI Research (Inner) - Translational AI (Outer)





Problem Definition

- Understand the business problem from BMW
- Review Literature & Background Research

BMW Data Acquisition & Preparation

- Historical data provided by BMW
- Data and Domain Understanding, ER model, Policies
- Data cleaning and preparation

Parts Forecasting Model Selection

- Develop parts forecasting model
- Research and compare existing parts forecasting models

Parts Forecasting Model Validation

- Validate model with actual (mock/ scrambled) data
- User Acceptance Testing (AI Material Planner)

Parts Forecasting Model Validation and Dashboard

- Deployment of model and Dashboard
- Evaluation path of low-risk parts

Monitoring

- Monitor Accuracy in live scenario

Specify and Prepare

Model

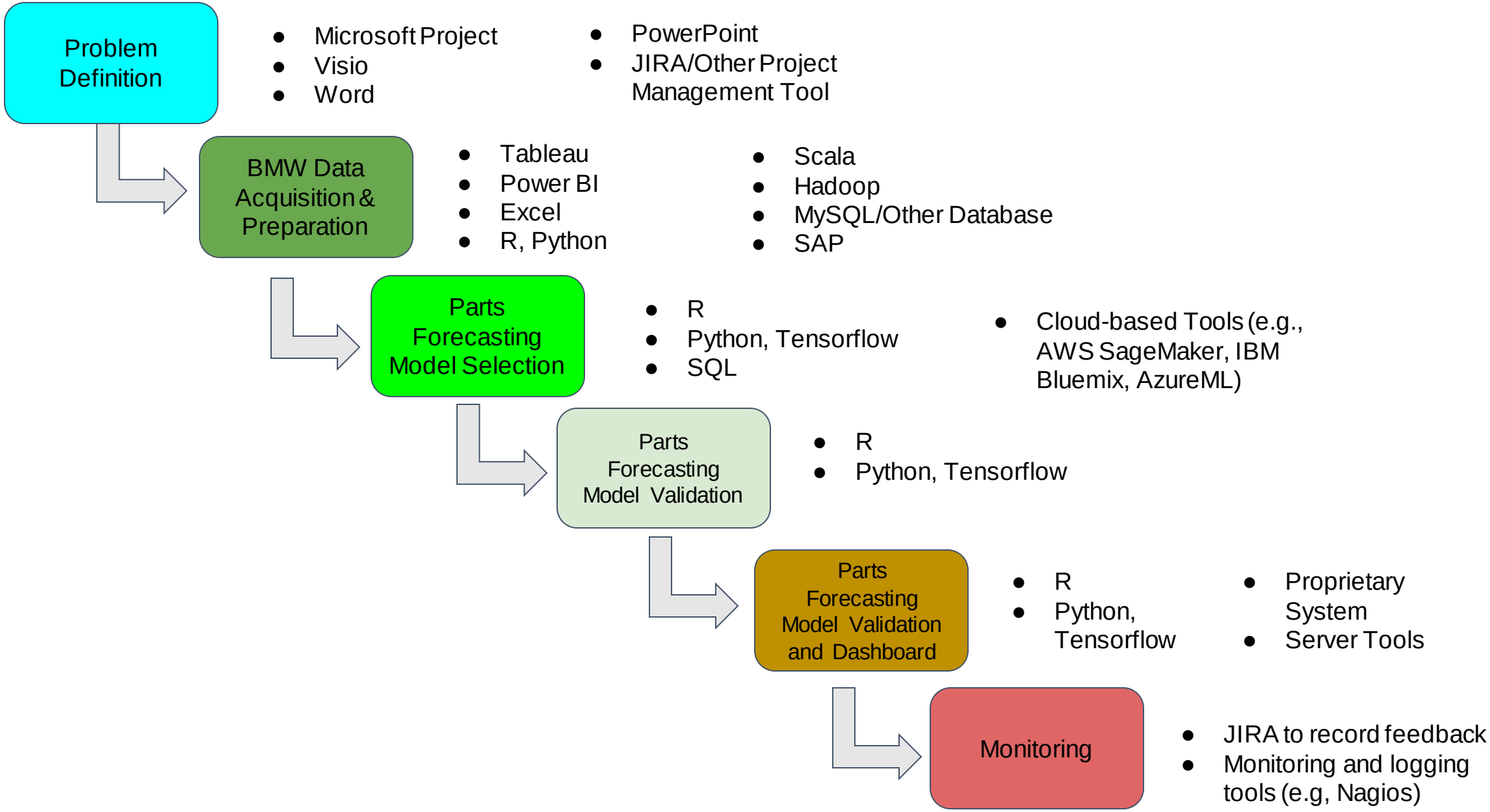
Analyze

Roll-out

Test and Monitor

MLOps

A Smart Model for Data Science Projects.
This model is based on Industry guideline such as [CRISP-DM (Cross-Industry Standard Process for Data Mining)] and experience of practitioners.


Problem Definition
Microsoft Project
Visio
Word
PowerPoint
JIRA/Other Project Management Tool
BMW Data Acquisition & Preparation
Tableau
Power BI
Excel
R, Python
Scala
Hadoop
MySQL/Other Database
SAP
Parts Forecasting Model Selection
R
Python, Tensorflow
SQL
Cloud-based Tools (e.g., AWS SageMaker, IBM Bluemix, AzureML)
Parts Forecasting Model Validation
R
Python, Tensorflow
Parts Forecasting Model Validation and Dashboard
R
Python, Tensorflow
Proprietary System
Server Tools
Monitoring
JIRA to record feedback
Monitoring and logging tools (e.g, Nagios)

Next step...

- Understand Data and Domain
- Identify the right method for parts forecasting model selection
- Apply Broad knowledge of many AI Techniques and choose the right one

PROJECT INTRODUCTION

Fraunhofer USA

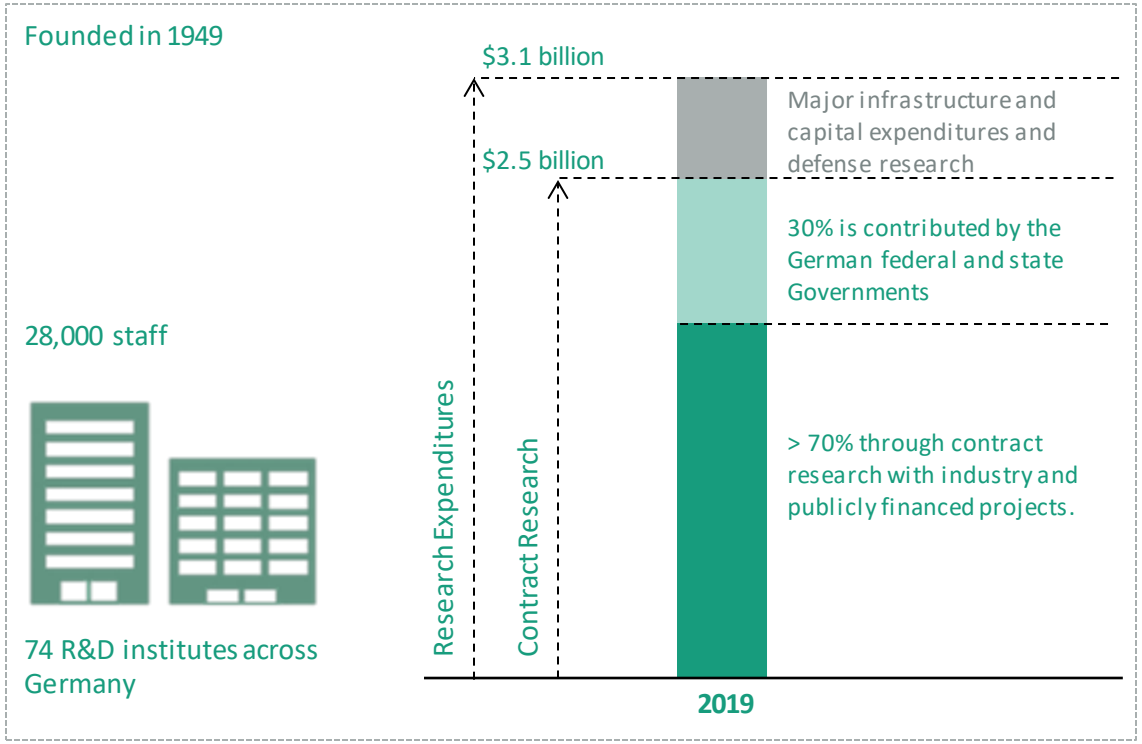
Tasks

The Fraunhofer Organization at a Glance

"Bridging the Innovation Gap."

Fraunhofer Gesellschaft

Since 1949: Applied research of direct utility to private and public enterprises benefitting society



Fraunhofer USA

Building the Fraunhofer competence Bridge since 1994 as a non-profit applied research organization

Center for Manufacturing Innovation CMI
- Energy Technologies, *Brookline, MA*
- Automation, *Brookline, MA*
- Biomedical Manufacturing, *Brookline, MA*

Center Midwest CMW
- Coatings and Diamond Technology, *East Lansing, MI*
- Laser Applications, *Plymouth, MI*

Center Mid-Atlantic CMA
- Software Systems Engineering, *Riverdale, MD*
- Biotechnology, *Newark, DE*
- South Carolina Alliance Office, *Columbia, SC*

Headquarter, *Plymouth, Michigan*

Univ of SC South Carolina

Fraunhofer USA

Fraunhofer USA

1. **Data**
   - When, how, and to what data shall we have access
   - Requirements regarding data access, data handling, and storage
   - Documents describing the data
2. **Interview**
   - Are there documents about the processes in supply chain planning
   - Documents that would help us prepare for the interviews with supply chain professionals
   - Planning the interviews - when and with whom should we start the interview process
3. **AI-based Material Planner Assistant (MPA)**
   - Assumptions
   - Dependencies
   - Constraints
   - Actors/Roles
   - User requirements
   - Expected design principles
   - What will be key performance indicators (KPIs)?
   - Acceptance criteria

DATA DISCUSSION

Working Lunch

DISCUSSION ON WAY AHEAD

Timeline, Group Meetings, Task Roadmap, Task Leads and Points of Contact, Objectives, Reporting, etc.