

Project: Bridge Inspection System

Enterprise/Domain: Federally mandated bridge inspection process. Regulated/coordinated by Federal Highway Administration. 600,000 bridges in USA. Average age 42 years. Many bridges deficient. All bridges must be inspected every two years. Deficient bridges must be inspected more frequently than every two years.

Enterprise Performance Measures and Targets:

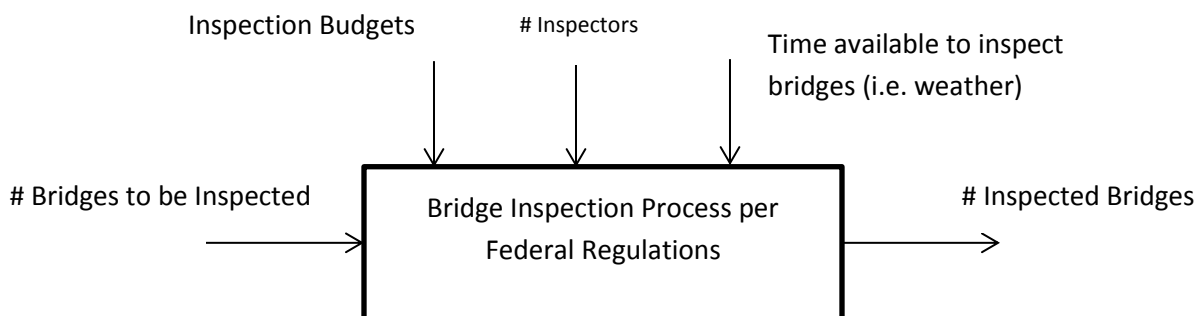
- Bridges are decaying leading to a increase in the count of bridges considered to be deficient each year. This is growing. (This is the NEED)
- Bridge inspection process has remained the same per Federal regulations (This is the SUPPLY)
- There is a growing gap between NEED and SUPPLY that can be fixed by improving individual bridge inspection process.

Other performance measures:

- Bridge accidents
- Bridge accidents on bridges that were inspected
- % Bridges Inspected
- Accuracy of Bridge Inspections
- Number of Inspectors
  
- Time to Inspect all bridges in a jurisdiction =  $\sum (\text{Time to Inspect Bridge (i)} * \text{Number of Inspections Required Every Two Years for Bridge(i)})$   
Note: Deficient bridges must be inspected more than once every two years.  
Note: Weather impacts times when bridge can be inspected
  
- Cost to Conduct Bridge Inspection of all bridges in a jurisdiction =  $\sum (\text{Cost to Inspect Bridge (i)} * \text{Number of Inspections Required Every Two Years for Bridge(i)})$
- Total Cost of Bridge Inspection = Cost to Conduct Bridge Inspection + External costs (e.g traffic due to lane closures)

Physical Process:

Inspection of a bridge (using visual and acoustic inspection)



### Performance Gaps:

**Bridges are decaying leading to an increased count of bridges considered to be deficient each year and needing inspection). This is growing. (This is the NEED)**

**Bridge inspection process has remained the same per Federal regulations (This is the SUPPLY)**

**There is a growing gap between NEED and SUPPLY that can be fixed by improving individual bridge inspection process.**

As the number of deficient bridges increases, the total time required to inspect all bridges in a jurisdiction and the total cost to inspect all bridges in a jurisdiction will increase.

The number of inspectors and budgets for inspections will remain the same (especially in period of fiscal austerity).

Goal of project is close the gap between growing costs/time and limited resources.

### Stakeholder Tensions:

Contract inspectors want more work (but safer conditions).

Inspection managers want spend less money and get more bridges inspected to meet federal mandates.

### Design Alternatives:

- (1) Existing process: manual inspection by visual and acoustic. Requires lane closures. Hazardous to inspectors. 95% accurate.
- (2) Semi-automated Process: use sensors to monitor bridge. Inspect only when and where needed. Reduce the need to inspect all bridges every two years. For deficient bridges, extend time between inspections.
  - a. Sensors with cables for power and communications
  - b. Sensors with low power comm. Remote data collection bu UAVs

Project: Small Package Delivery Air Vehicle

Enterprise/Domain:

Growth in e-commerce (14% per year?) has led to increased demand for small package delivery.

Also demand for small package delivery for food (i.e. take-out), maintenance (i.e. rapid parts supply to remote locations), ....

Technology advances has provided capability to support these small package delivery needs.

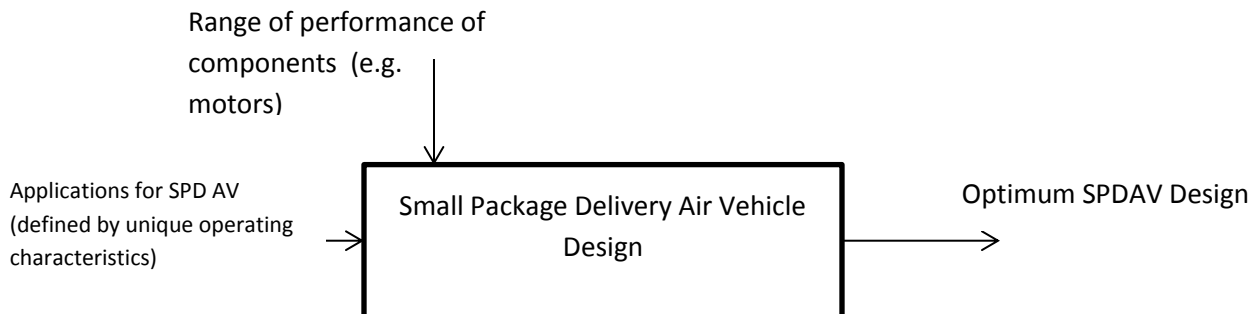
The organizations that could use SPD services are generally not engineering organizations with personnel with engineering skills and knowledge to design or select a SPDAV for their applications.

Enterprise Performance Measures and Targets:

- Time, Cost, Reliability for delivery of Small Packages
- Safety and Security of Delivery
- No time and effort for SPDVA design (need to outsource or purchase off-the-shelf)

Physical Process:

Design of SPDAV to meet specific application requirements



Performance Gaps:

High number of diverse applications for SPDAV vs. Low number of off-the-shelf designs.

Knowledge gap service providers need vehicle to meet application requirements, but do not have knowledge skills to determine what type of vehicle.

Small package delivery time/cost/reliability current (i.e. car/truck/bicycle delivery) vs SPDAV delivery

Stakeholder Tensions:

*Main Stakeholders:*

Service providers need best design for application – willing to pay for design service

SPDAV manufacturers – want to produce in volume (do not want to be in customization business). Pick designs with broadest applications.

**Manufacturers want Service providers to buy their design as-is. Do not want anyone suggesting alternative designs.**

*Other Stakeholders:*

Airspace Regulatory Authority (i.e. FAA Certification) – want to ensure high quality and safe designs. Can SPDAV solve this problem?

Design Alternatives:

- (1) Existing Process: pick existing SPDAV designs off-the-shelf
- (2) Proposed Process: use application specific requirements to design optimum vehicle for application based on detailed models of performance

## Project: A/C Production

### Enterprise/Domain:

Final assembly of fighter aircraft (e.g. F-35). Thousands of parts are assembled into sub-assemblies. These sub-assemblies are joined into four main assemblies (fuselage, wings, ...). The four main components are mated in final assembly process. Each assembly takes place in one or more stations. There are 23 stations for the four main components and the final assembly. The focus of this project is these 23 stations.

At each stage in these processes there are opportunities to leave foreign objects behind which can damage the aircraft during assembly and flight. These foreign objects include: tools, parts (e.g. washers, screws, rivets), food, and other non-aircraft objects.

Production procedures prevent foreign objects by tracking all tools and parts. Also assemblers are trained to avoid foreign objects. Finally, all assemblies are inspected. If a tool or part is reported missing, the assembly is inspected. The assembly is also inspected before moving to the next station.

The inspection of large assemblies is conducted by a visual inspection. Inspectors know where to look from experience to find foreign objects. However, foreign objects that are not in line-of-sight are not detected by this method.

### Enterprise Performance Measures:

#### *Production Facility*

- Scheduled production vs actual production
- Planned time and cost for each aircraft

#### *Individual Aircraft Production*

- Production time for each aircraft/assembly. A component of production time is rework time due to improper assembly and foreign objects.
- Staff required for each station
- Quality of each station (i.e. accurate assembly, foreign objects)

### Physical Process:

Foreign object inspection at each of 23 stations.

Inputs to physical process::

- Distribution of Time in each station.
- Probability of foreign objects in each station.
- Distribution of rework time for each station for each type of foreign object.

Outputs: to physical process :

- Distribution of Time in Production
- Distribution of Time at each station (including rework and FOD)
- Probability of FOD not detected

Parameters for physical model:

- Probability of detecting FOD dependent on the type of inspection (i.e. visual, Xray1, xray-2, x-ray 3)

#### Performance Gaps

- Target foreign objects vs actual foreign objects in assembly (goal is zero)
- Target FOD vs Actual FOD
- Target FOD Inspection time vs Actual FOD Inspection Time

#### Stakeholders Tensions:

Assemblers glad to have assistance with FOD

Production Managers want improved FOD as long as it does not affect production

FOD Inspectors want to get job done, but may not want to be replaced by automation. Not likely cost solution would need oversight.

#### Design Alternatives:

Existing process: visual inspection

Proposed process: X-ray inspections.

Design alternatives X-ray: transmission vs backscatter

Design Alternatives: Mounting: Fixed, rail, articulating arm ....

Design Alternatives: Power/Dosage (depends on materials in assembly)

## Project: Human Factors Certification

### Enterprise/Domain:

A cockpit “device” is any equipment that is installed in the flightdeck of a modern airliner. All devices must be certified by the regulatory authority before they can be installed. Part of the certification is a “human factors” certification to eliminate poor designs that can result in “crew error” contributions to aircraft accidents. A new rule, FAR 25.1302, requires manufacturers to demonstrate compliance for **all** tasks performed on the device.

Compliance can be demonstrated by manual inspection of the device (i.e. knob can be reached by pilot from sitting position, two adjacent knobs cannot be confused in a dark cockpit, displays can still be read in direct sunlight, ....). These tests just evaluate only the physical characteristics of the device. To test the way the device is used must be done by performing tasks. These tests are typically conducted using Human-in-the-loop testing. Since these HitL tests are time and cost prohibitive (i.e. 20-30 subjects, each task takes about 15 minutes on average including set-up time). HitL testing is done only on a sample of tasks.

A typical flightdeck has approximately 1200 tasks. There is not enough time and money to perform HitL testing on all the tasks.

A modernization initiative is underway in the US (NextGen) and Europe (SESAR). This initiative has been forecast to result in a large number of new devices to be certified to support the Operation Initiatives (OI's) proposed for NextGen SESAR.

One other characteristic of the domain, is the regulatory authority does not have enough inspectors/specialists, so they rely on industry representatives. To perform the inspections/evaluations. These industry representatives are paid by their companies to find faults in the devices. This is a conflict of interest.

### Enterprise Performance Measures

- Number of devices waiting to be certified
- Number of devices certified
- Quality of certification (i.e. did a certified device contribute to an accident?)

Note: Devices waiting to be certified incur large expenses to manufacturers who cannot get revenue for their products until they are certified.

### Physical Process:

Human Factors certification of devices. Specifically, the evaluation of all tasks to be performed on the device as required by FAR 25.1302.

### Key Measures:

- Time to perform evaluation for all tasks
- Cost to perform evaluation for all tasks
- Accuracy of evaluation

Process for evaluating a device:

Inputs: Procedures/tasks (i.e. list of operator actions and their cues), characteristics of the device

Parameters: Distributions for categories of operator actions that compose each task, time “penalty” for operator actions with competing cues.

Outputs: Distribution of time on task

Performance Gaps:

Backlog of devices waiting for certification

Stakeholder Tensions

Designated Engineering Representative (DER)

- Is an employer of the device manufacturer
- Is required to FIND problems for regulator and NOT FIND problems for employer.
- Because evaluation is subjective, employer puts pressure of DER to pass the evaluation

Design Alternatives:

Existing Process:

- Manual Inspection
- HitL with subjects in experiments

Proposed Process:

- Automation of HitL by simulating subjects in experiment performing all the tasks on a device.