Patient Flight Path Analytics: From Airline Operations to Healthcare Outcomes

By Dale Sanders, David Crockett, PhD, and Justin Gressel

Introduction: Learning from Airline Operations

Those of us who work in healthcare often use airline operations as a metaphor for the value of constant safety and quality improvement. At Health Catalyst, we take the airline metaphor a bit further. We see that airlines are motivated to precisely predict the flight path of an aircraft to its destination, and then the turnaround of that aircraft back into operation and off to its next destination as quickly, safely, and cost effectively as possible. So, we applied these general concepts and specific predictive algorithms to improve the prediction and outcome of a patient’s “flight path” through the healthcare system, to help ensure this patient a fast, safe, and cost effective return to optimal health.

At Health Catalyst, we developed a predictive analytics framework for patient care based upon concepts from our past experience in predicting aircraft flight operations known as “sortie turnaround times” or “aircraft turn-times” and “sortie generation rate.” In simple terms, this refers to the time it takes to land an aircraft, offload its cargo, reload new cargo, and return the aircraft to functional status. In commercial aviation, as well as military operations, predicting, managing, and optimizing these turnaround times is critically important to the success of the mission and minimizing operating costs.

Historically, healthcare has not faced the same level of customer service and pricing pressures as the airline industry. Health systems can leverage this flight path metaphor for optimizing treatment and cost to create the best patient outcomes—not in terms of throughput and volume, but flight efficiency, successful missions, and flight safety.

Metaphors Allow for Creativity and Problem Solving

Metaphors are an effective technique to communicate new concepts and ideas based on their similarities to past, well-known concepts. Designers, architects, and engineers use metaphors to stretch creativity and increase their understanding of unfamiliar problems by contrasting them with known situations that share parallel concepts. One of the more recent and famous metaphors was the personal computer user interface that was designed around an office
desktop. Another example is the comparison and parallels between a virus in nature and a virus on a computer. Both can be described and managed using concepts from epidemiology. Personal health maintenance is often juxtaposed to automobile maintenance, where preventive care is the norm to avoid long-term, expensive repairs.

We believe that human behavior and problem solving are largely repeated in patterns across time and domains, and by recognizing these patterns in one domain and applying them to another domain, we can more quickly, creatively, and efficiently solve problems than if we tried to solve it in a vacuum, as if the problem had no precedence in any other domain. A number of studies has shown that people with broad backgrounds and capabilities, combined with years of experience, have a tendency to be more effective in seeing these patterns and applying metaphors to creatively solve problems than novices with narrow backgrounds. Hiring and cultivating a corporate culture with people that have these diverse backgrounds is a very deliberate strategy for fueling creativity. It is this basic, cultural philosophy at Health Catalyst that helped us frame the prediction of patient outcomes within the metaphor of predicting aircraft turnaround times.

Ways Aviation and Healthcare Are Similar

Again, healthcare is often described in terms that parallel the aviation industry. And this is particularly true in the role that variation in both airline and healthcare operations contributes to a decline in passenger and patient safety, respectively. Harvard medical school professor and author, Atul Gawande, author of The Checklist Manifesto, draws heavily upon the history of aviation checklists, starting in the U.S. Air Force, as a metaphor and means for increasing patient safety and decreasing variability in healthcare processes.

Extending the aviation metaphor a bit further, we can see two other similarities to healthcare:

1. The flight path of an aircraft is similar, conceptually, to the flight path of a patient’s health and treatment; and
2. The goal of aircraft turn-time is to return an aircraft to serviceable duty as quickly and efficiently as possible, which is, in essence, the same goal as healthcare delivery to a patient.

Flight Paths for Aircraft and Patients

Below is a diagram that depicts the flight path of an aircraft, along with the variables and processes for turning that aircraft back into functional operation.
It is worth noting in this diagram that there are four different managers involved in the handling of aircraft to ensure their safe and timely return to service: (1) AMAN, the inbound aircraft Arrival Manager, acts as a liaison between the aircraft and airport ground operations; (2) SMAN, the Surface Manager, who is responsible for the aircraft after it has landed and arrived at the facility and is transitioning into the gate or maintenance facility; (3) GMAN, the Ground Manager, who oversees the majority of maintenance and logistics processes associated with the turnaround of the aircraft; and (4) DMAN, the Departure Manager, who oversees the exit of the aircraft to its next destination.

As illustrated in Figure 2, the parallels to care managers, integrated practice teams, home care, and health coaches in healthcare are apparent.

Figure 1: The management of an aircraft’s flight path and turnaround time
(Source: “Turnaround Prediction with Stochastic Process Times and Airport Specific Delay Pattern,” Center for Air Transportation Systems Research, October 2011.)

Figure 2: The metaphorical Patient Flight Path and turnaround time
The parallels between airline operations and healthcare delivery as described above are fairly obvious. Patients arrive at the healthcare delivery organization. Both scheduled and unscheduled arrivals are important to model, the latter being especially important to address with predictive algorithms; the patients are treated and the treatment might include a series of encounters, making up an episode of care; and when deemed healthy for “takeoff,” the patient is discharged back to their next destination—hopefully a functional life. As in aircraft operations, the goal is to return the patient to functional status as quickly and cost effectively as possible.

**Predictive Analytics in Healthcare: Applying the Concepts and Algorithms**

Precise predictions of these turnaround times are crucial to the success of commercial and military aviation. Predictive algorithms have played a significant role in this environment for more than 30 years. A 10-minute faster average turn-time can increase airplane utilization by eight percent and lower aircraft operating costs for a typical, single-aisle airplane by two percent. Since 1978, commercial passenger aircraft loading times have increased 51 percent, causing a dramatic increase in aircraft operating costs and passenger dissatisfaction.

The variables that affect the turnaround times for commercial aircraft and feed into the predictive models, comprise the “flight profile” of the incoming aircraft and include the following variables and more:

- Aircraft type
- Aircraft seating arrangement
- Crew rest and crew availability
- Distance to next destination
- Estimated arrival time to gate
- Existing fuel load
- Flight crew
- Gate availability
- Ground crew and equipment availability
- Number of checked bags for deplaning
- Number of checked bags for enplaning
- Number of passengers deplaning
- Number of passengers enplaning
- Ramp type for passenger deplaning and enplaning
- Refueling time
- Required maintenance tasks
- Taxi route after landing
To illustrate the parallels to clinical flight paths, the Health Catalyst predictive framework would use the following variables in a patient with diabetes:

- Age
- Alcohol use
- Annual eye exam
- Annual foot exam
- Average time between visits
- Blood pressure
- BMI
- Distance to care clinic
- Encounter charges
- Gender
- HemA1c
- Lipids (LDL)
- Marital status
- Medications
- Nephrology
- Number of visits per year
- Patient satisfaction score
- Time at current address
- Tobacco use

We look for patterns that influence patient outcomes. For example, in this diabetes patient, the flight profile patterns would be associated with two types of outcomes: (1) Diabetic control according to HmA1C levels; and (2) The absence of progression toward the following diabetic complications:

- Cardiovascular Disease
- Cataracts
- Death
- Diabetic Ketoacidosis
- Diabetic Preeclampsia
- Diabetic Retinopathy
- Erectile Dysfunction
- Foot Ulcer
- GI Complication
Three Uses for Patient Flight Paths

Using this airline metaphor as a backdrop, Health Catalyst developed a proprietary predictive analytics framework for patient care and outcomes that borrows from both the concept as well as the algorithms used in the airline industry. Specifically, Health Catalyst is applying this framework to:

1. Predict the unscheduled need for healthcare services, based upon a risk profiling and stratification process.

2. Based upon the incoming “flight profile” of the patient in need of healthcare services, whether scheduled or not, predict the optimum protocol for treating that patient that will return him to his highest functional health status, as quickly and cost effectively as possible. The protocol in this context is broader than the traditional clinical protocol and includes the timing, costs, location of care, and arrival of people and equipment that contributed to the best patient outcomes, financially and clinically.

3. Model scenarios in which the treatment protocol and clinical profile of the incoming patient are modified for sensitivity analysis to determine the impact on the patient’s turnaround time to functional health status. A patient’s glimpse into the future can provide powerful motivation for change. Avoiding healthcare costs and life-altering disease complications may provide the motivation patients need to change their behavior and the impetus healthcare system leaders need to change healthcare operations.

Creating the Optimized Patient Flight Path

Using a combination of machine learning approaches (such as regression, naïve Bayes, decision trees, sequence clustering, and Markov sequencing), the Health Catalyst clinical flight path models account for both historical cohort trends and forecast likely patient outcomes in terms of cost and complications.

As depicted in Figure 3, the concept of calculating an optimized Patient Flight Path requires at least three layers of predictive functionality.

These three layers are:

1. A predictive risk score specific to a cohort of patients and the clinical and social variables associated with best practices for treatment and cost;
Figure 3: Combining clinical risk, financial risk, and “what if” scenario planning

2 A customized care recommendation specific to a given patient’s flight path and the highest statistical impact in terms of health and cost with the intention to slow or stop their current disease progression; and

3 “What If” functionality to simulate and visualize how a slight change in leading variables may impact out-of-pocket costs, total costs to the healthcare provider, and avoidance of poor outcomes likely to occur without proper and timely intervention.

Figure 4 shows the ability to drill into the population health level, down to the clinical details of specific patients. Tying back to airline

Figure 4: Drill down to specific patient clinical data for root analysis
operations, this is equivalent to viewing the overall flight path and turnaround data for Chicago O’Hare, then drilling down to specific airline and aircraft data for root analysis.

We use an association (basket) analysis of diabetic complications to assist physicians in providing a treatment recommendation for patients. The numbers in the table generated by the analysis represent ratios of observed to expected co-occurrences of complications\(^1\). By looking at the large ratios, it becomes clear what complication pairings a patient is more at risk for above and beyond the probability faced by the general population. This information is incorporated into treatment recommendations that communicate the likelihood of a patient’s flight path encountering one or more of these complications. Underlying the conversation is the historical flight path of similar patients and their treatment pathways.

Figure 5 shows the results from the association analysis of complications from patients being treated in a medium-sized physician specialty group that is also a federal Accountable Care Organization.

1 The numbers in the table represent the ratio of the observed co-occurrences of two complications to the expected co-occurrences, where the expected co-occurrences are a function of the individual complication rates under the assumption that they are both independent of one another. A ratio of one indicates the observed co-occurrence is to be expected, whereas a ratio greater than one indicates that the complications co-occur more often than expected.
Conclusions and Future Work

The benefits of problem solving using metaphorical framing include contributions to creativity, as well as understanding. We have found our notion of a Patient Flight Path to be useful at both the conceptual level, as well as at the predictive algorithm implementation level. We have also found the framework to be extensible to any patient cohort, diabetic patients being only one example. Health Catalyst is actively extending the framework to other patient types at customer sites.

References


About the Authors

Dale Sanders has been one of the most influential leaders in healthcare analytics and data warehousing since his earliest days in the industry, starting at Intermountain Healthcare from 1997-2005, where he was the chief architect for the enterprise data warehouse (EDW) and regional director of medical informatics at LDS Hospital. In 2001, he founded the Healthcare Data Warehousing Association. From 2005-2009, he was the CIO for Northwestern University’s physicians’ group and the chief architect of the Northwestern Medical EDW. From 2009-2012, he served as the CIO for the national health system of the Cayman Islands where he helped lead the implementation of new care delivery processes that are now associated with accountable care in the US. Prior to his healthcare experience, Dale had a diverse 14-year career that included duties as a CIO on Looking Glass airborne command posts in the US Air Force; IT support for the Reagan/Gorbachev summits; nuclear threat assessment for the National Security Agency and START Treaty; chief architect for the Intel Corp’s Integrated Logistics Data Warehouse; and co-founder of Information Technology International. As a systems engineer at TRW, Dale and his team developed the largest Oracle data warehouse in the world at that time (1995), using an innovative design principle now known as a late binding architecture. He holds a BS degree in chemistry and minor in biology from Ft. Lewis College, Durango Colorado, and is a graduate of the US Air Force Information Systems Engineering program.

David K. Crockett, Ph.D. is the Senior Director of Research and Predictive Analytics. He brings nearly 20 years of translational research experience in pathology, laboratory and clinical diagnostics. His recent work includes patents in computer prediction models for phenotype effect of uncertain gene variants. Dr. Crockett has published more than 50 peer-reviewed journal articles in areas such as bioinformatics, biomarker discovery, immunology, molecular oncology, genomics and proteomics. He holds a BA in molecular biology from Brigham Young University, and a Ph.D. in biomedical informatics from the University of Utah, recognized as one of the top training programs for informatics in the world. Dr. Crockett builds on Health Catalyst’s ability to predict patient health outcomes and enable the next level of prescriptive analytics – the science of determining the most effective interventions to maintain health.

Justin Gressel joined Health Catalyst in January of 2015 as a senior data scientist. Prior to coming to Health Catalyst, he worked both in industry (Disney and Great Wolf Resorts) and in academia as a marketing professor. Justin has a PhD in Marketing from Purdue, and an MBA and baccalaureate in Statistics from Brigham Young University.