Perspective on Crew Management:
The Secret Behind Proactive Risk Reduction

What is behind the type of optimization that proactively reduces risk in airline crew planning? Not the type that only respects over-simplified rules, based on maximum duty and minimum rest times in various ways, but the one that directly applies the science of our physiology? The type that constructs pairings and rosters, to avoid and reduce risk in the first place, not only pointing out the bad patterns afterwards. What is the secret sauce?

Let us start with a short recap of optimization for crew planning problems. Crew pairing and crew rostering optimization problems are often extremely challenging to solve. All hard constraints of the planning problem (rules, amount of crew per base etc.) need to be respected, while the optimiser searches for solutions that evaluate to the lowest overall cost in something called an objective function. The objective function, or cost function, puts a price on everything important, such as; total number of duty days, layovers, aircraft changes, other robustness and quality-of-life aspects for the crew. It is not unusual for an airline implementation to have over a hundred different cost elements 'explaining' to the optimiser how desirable a solution is.

The optimizer then uses clever math to consider an enormous amount of possible solutions, and applies a method called column generation to quickly find the best overall solution with the lowest total ‘cost’. It is up to each airline to ‘explain’ their unique priorities to the optimiser via the objective function; tuning the weights for different cost elements. As an example, in order to achieve a more robust solution, the cost of an aircraft change in a tight crew connection can be increased. This will result in the optimizer favouring solutions where crew are more frequently kept together with the aircraft in hub turns, and a plan that is more resilient to disruptions on the day. The impact of assigning higher weight to one aspect is of course that other aspects may often take a hit; perhaps resulting in extra duty days or layovers.

So what is the secret sauce that enables taking human physiology into account while building these pairing and rostering solutions? These three things;

a) an extremely fast (and accurate) bio-mathematical model,
b) a real-time interface between the model and the application, and
c) a cleverly designed penalty on fatigue risk feeding into the objective function.

Starting with the performance aspect; a mid-sized roster optimization problem (some 1,000 crew), as well as a complex pairing problem, may take a few hours for an optimizer to ‘hammer out’ to the lowest possible cost. This even on the fastest computers, where these jobs run on many processors in parallel. During that run time, many thousands of legal pairings or rosters
are generated and priced every second. A fatigue model connected to this process, serving as a detailed proxy for human physiology, will therefore be called upon several thousand times per second, and asked to return the predicted alertness at various points in time for a chain of activities. This requires a bio-mathematical model that is extremely fast. The model will need to be built from the beginning with this in mind, minimising the amount of CPU instructions used for each call.

The model also needs to communicate over a real-time interface, as there is simply not time available for sending files back and forth. For this reason, the model will need to be a so-called linked library, making the model become a part of the application itself. A part of the optimizer.

Lastly, the output of the model must be transferred into a cost that can be “experienced” by the optimizer, guiding it to solutions with lower risk. The way this is done is by having each flight contribute with a cost relative to the average predicted level of alertness during the flight, or using for example the prediction at top of descent. The cost is designed in such a way that it imitates the development of risk in human beings when the alertness drops; the risk of a lapse, slip, mistake or violation will accelerate when the alertness level drops. A drop in alertness from 3,000 to 2,000 will result in a lower cost increase, compared to a drop from 2,000 to 1,000. By having risk modelled in this way using a penalty, rather than just using a cut-off rule at a certain alertness level, it is possible to reduce the overall sum of fatigue risk in a solution. This is then tremendously more efficient than only using a cut-off rule, something that would easily result in pushing flights “to the limit”. But one does not exclude the other; a clever penalty can also be combined with using a hard rule if so desired.

So, that is the secret sauce that enables proactive risk reduction in concert with reaching other objectives. However, the integration between optimizers and bio-mathematical fatigue models not only lends itself to proactive risk reduction within the rules, but also an ability to improve those rules to release higher crew efficiency. But that is another story…

Further reading:

- Aligning Rules With Human Physiology
- SPIs found in BAM/Concert/CrewAlert
- Jeppesen Concert

The Boeing Alertness Model (BAM) is designed for real-time communication with application with extreme performance requirements.