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Whitepaper

# AIRLINE DISRUPTION MANAGEMENT

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# AIRLINE DISRUPTION MANAGEMENT

## *A Complex Problem Seeking Solutions*

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## 1. EXECUTIVE SUMMARY

Irregular Operations (IROPS) constitutes one of the most difficult problems the airline industry faces. Bad weather events can have a more devastating impact on airlines than they would on any other mode of intercity transport. Sometimes, an airline is forced to shut down operations at a key airport entirely. Even where the airport can remain open, capacity is reduced, delays build up, and eventually cancellations are required to get the airline back on schedule. The disruption will displace flight crews from their normal rotations, necessitating further corrective control actions to restore order to schedules, which in turn can disrupt operations still further.

The consensus estimate of the cost of these disruptions to the airlines is about 5% of airline revenue, or about USD 35 billion worldwide. However, this is almost certainly not the whole story, as it does not include the cost of lost productivity to travellers and lost business for support industries such as hotels, business services, and tourism. The total value, including the value of all the lost productivity and down time, is probably more like $60 billion.

This problem has been around since the beginnings of the airline industry, yet it has historically been resistant to all attempts to solve it. Traditional IT development methods of writing specifications and then building a system that meets them have not succeeded because the specifications will continuously evolve as new capabilities are developed. While prototypes for partial solutions have provided some limited help, the constantly changing nature of IROPS situations often means that a solution may become outdated just a few minutes after it is devised. In general, the IROPS recovery solutions developed thus far have been more aspirin than antibiotic: i.e., they address limited symptoms but are highly unsatisfying as a cure.

While IROPS is certainly a nasty problem for airlines, it also represents an opportunity in that any improvement in mitigating large-scale weather events will reduce costs and increase airline profitability. If customers perceive that a particular airline is doing a better job on IROPS than its competitors are, they will drive market share to that airline. Quite simply, mitigating IROPS represents an opportunity that no one associated with the airline business can afford to ignore.

## 1.1. WHY IROPS HAS BEEN SUCH A DIFFICULT PROBLEM TO SOLVE

Throughout its over 100-year history, the airline industry has overcome numerous technical and financial challenges through a continuous drive toward innovation and productivity, yet solutions for IROPS have remained elusive. We have identified five major drivers that have contributed in a significant way to the general lack of progress:

- Soft costs – Hard costs such as aircraft operations, hotel/meal vouchers, and staff overtime are well known, but soft costs such as customer service and passenger delay time may well represent the key cost drivers of an IROPS situation. Everyone acknowledges the importance of these costs, but they are much more difficult to quantify.
- Metrics – There is no consensus within the industry of how to measure IROPS costs, and therefore no standards on how to measure savings from better performance.
- Human bandwidth – Key IROPS decisions are made by the people in the Operations Control Center at an airline. People are flexible, but do not have the bandwidth to process the avalanche of data that must be taken into consideration when making operate/cancel/delay decisions on a minute-to-minute basis. Because all the resources and processes interact with each other, the bandwidth problem cannot be solved simply by adding staff.
- Data integration – Any IROPS solution, of any level of complexity, must be driven by a current view of all the airline's resources and what they are scheduled to do over time. In addition, external factors such as current weather, competitor activities, and air traffic control bottlenecks may constrain solutions. For any IROPS software to be effective, all of these internal and external data sources must be available, because any of them can represent the key driver or constraint for any given IROPS recovery scenario.
- Senior management support – Until recently, senior airline executives did not view the Operations area as being a key revenue driver or enabler. Consequently, any attempts to justify investment in IROPS recovery tools were usually viewed as high-risk projects with little or no impact on the company bottom line. However, the recent emphasis on unbundling airline services and generating ancillary revenues has shown that better

schedule reliability enhances the value of those ancillary services, both to the airline and to customers.

A positive trend is that current development projects across the airline industry have begun to address each of these issues. For example, more data is easily accessible through centralised data servers that bring together data from many sources. Executives are recognising the importance of customer loyalty and similar soft costs, and are adding them to their business cases. The major impediments to progress are gradually evolving away.

## 1.2. CURRENT INITIATIVES

Significant growth of investment in IROPS solutions began around 2010. Both airlines and solutions providers have been participating, for different reasons:

- Vendors have focused on developing generic solutions that can benefit many potential customer airlines.
- Primarily large airlines have done internal development tailored to the characteristics of their operating model that they believe cannot be addressed by generic solutions.

The initial frontier for development was in passenger re-accommodation after a cancelled or severely delayed flight. This has now evolved into development of automated solutions for rebalancing aircraft rotations in order to keep the non-disrupted parts of the airline running smoothly and avoiding escalation of the problem resulting from consequences of the disrupted parts. There has been some development of solutions to repair crew trips broken by disruptions, which is technically the most difficult component of IROPS due to the complex duty and rest limitations. A few vendors are offering products that offer push-button solutions for some portion of the problem, although orchestrating complex solutions is still a challenge for every airline.

Despite this progress, it is safe to say that no airline or vendor yet has a “killer app” that will enable it to make a case that it solves IROPS problems significantly better than its competitors and thereby attract more market share. There is significant investment activity, and there are many innovative ideas that are getting some serious review from the airline community. Thus far, however, there have been no significant market breakthroughs.

At the same time, the current trend toward unbundling airline services and creating sub-products that generate revenue has been a cornerstone of the industry's financial improvement. Improving response to IROPS situations can be considered an "enabling technology" that will further support refinement of the sale and delivery of those ancillary services. As long as that dynamic persists, the search for comprehensive solutions to the IROPS problem – and the associated R&D investment – is certain to continue.

## 1.3. PROGNOSIS

In many ways, the progression of solutions for the IROPS problem mirrors the state of the smartphone market around 2005. At that time, phones were just beginning to have keypads. One could download emails to a phone, but responding to an email was clumsy. Internet access was slow and had few tools supporting it. The concept of phone apps did not exist. The release of the first iPhone in 2007 and Android phones shortly thereafter largely solved all these problems. We expect a similar progression for airline IROPS solutions in the next few years.

Within the next 3-5 years, we anticipate that an airline or vendor will develop a comprehensive solution package that changes the game. As was the case with iPhone, being first mover will be a significant but not overwhelming advantage. Airlines and vendors that respond quickly to adopt the new technology may be able to improve upon the initial successes by adding their own ideas as well as by avoiding the mistakes of the pioneering firms. A cautious, wait-and-see approach could be very damaging if the state-of-the-art progresses rapidly after the first breakthrough, which is likely to happen once an innovation catches on with its target market. For that reason, both airlines and vendors need to continue to actively pursue solutions for the IROPS problem, and stay on top of developments in both communities.

Besides attracting attention and airline users, the breakthrough product or products will almost immediately stimulate follow-on development projects in a number of different dimensions. For example, there will be refinements to handle low-level details that may not have been cost-effective to address in the initial development. Tools to predict the extent of a problem or the mitigation effects of a solution will certainly improve as well. Airlines will be able reach out to upstream/downstream providers

of travel services such as hotels, seeking to coordinate their respective resources in order to provide an overall better experience to travellers.

IROPS is currently an unsolved problem that is not going to stay unsolved very much longer. Everyone within the airline community, regardless of role, needs to stay on top of development efforts for IROPS solutions because of the real value it provides to airline operational performance and customer satisfaction. In turn, those improvements will translate to bottom-line financial performance improvement. That is a compelling reason why IROPS should be top-of-mind for everyone in the airline community.

## 2. THE PAIN OF AIRLINE DISRUPTIONS

Every frequent traveller has at one time or another experienced major disruption in his or her trip plans due to flight cancellation, diversion, missed connection, or simply a very long delay. Whatever goals the traveller(s) had for their trip – whether it was a business meeting, a vacation, or a family occasion – any major delay can put the entire value of that trip in jeopardy.

While there are occasional major Irregular Operations, or IROPS, due to (controllable) computer or facilities failures, the vast majority of these events are the result of (uncontrollable) weather. Bad weather has a bigger impact on aviation than on other modes of transport. In an average thunderstorm, for example, automobile and train traffic may proceed with little impact, while airline flights will be grounded until the storm passes and major takeoff and landing patterns can navigate well away from its outskirts. Meanwhile, passengers are delayed – not only from reaching their destinations, but also from proceeding with their lives.

The airline experiencing the disruption suffers as well. Airline schedules are a complex logistics problem, and any significant delay means that aircraft and crews are out of position, not just for the affected flight but very likely for the remainder of the day and possibly beyond. The inability to bring passengers to their destinations means additional costs for rebooking/rescheduling their itineraries. Disrupted customers will complain, tempers will run high, and no one affected will be happy. Ultimately, airline profitability will take a hit. According to a recent FAA study, the cost of IROPS events to U.S. airlines is about $8 billion, or about 6% of revenue. If this percentage is applied

to the worldwide market of $710 billion (2016 estimate), then the total cost is about $42 billion, which is reasonably consistent with the estimate of $35 billion given previously. If IROPS events could magically disappear throughout the world, airline profits would more than double.

Even the seemingly simple task of defining what constitutes a solution to an IROPS problem is not easy, because any actions taken will affect aircraft flows, crew assignments, and passenger itineraries in different ways. For the purposes of this white paper, however, we will define an "IROPS solution" as a set of control actions (e.g., cancellations, delays, re-plans, reassignments) that re-establishes continuity in the planned flow of aircraft and crews such that all passengers can reach their final destinations as soon as possible. There are no explicit time limits, but (obviously) a solution developed quickly is better than the same solution developed over a longer period.

In this paper, we will explore the IROPS problem in some depth, at a level that should be of interest to everyone in the airline community, including suppliers, customers, IT providers, and the airlines themselves. We will explore why IROPS has been such a complex and frustrating problem historically, what airlines and vendors have done to mitigate its effects, and why not much progress has been made.

Then we will analyse recent developments, which have created a more favourable climate for airlines making investments in the IROPS problem. Although no one has yet "solved" it in terms of finding an approach for bringing the airline back up to normal operations quickly, there is every reason to believe that some leading-edge airlines will soon have methodologies for dealing with the IROPS problem in a meaningful way – a path that other airlines can follow to achieve similar results. Ideally, new technologies can be adopted downmarket within the industry so that eventually, everyone is able to take advantage of them.

Finally, we will look ahead to project what the IROPS mitigation solution of the (near) future looks like. We will assess what airlines need to do to align their processes with a much more data-driven business environment. That not only augurs well for finding good solutions to the IROPS problem, it will also open up additional opportunities for increasing revenues and reducing costs that will come from better anticipation of events and a faster response to them.

## 3. WHY AIRLINE DISRUPTION HAS BEEN A DIFFICULT PROBLEM TO SOLVE

Given the major damage that large-scale weather events inflict on airline operational integrity and performance, one might assume that airline managers would devote significant resources to this problem in an attempt to solve it, or at least mitigate some of the most painful effects. Until recently, however, this has generally not happened. Furthermore, in the comparatively rare cases where an airline did put forth significant investment in mitigating disruptions, those investments rarely produced meaningful returns. In this section, we will explore five major factors that have contributed to these difficulties. While none of them individually may have been insurmountable, the combination of all five certainly has been.

Despite these problems, the airline industry is now doing better financially and has been making significant investments in IROPS mitigation systems for the last several years. Operational managers and developers are currently working to overcome all the difficulties that have slowed progress in the past. It is highly likely that satisfying solutions will emerge soon.

### 3.1. HARD AND SOFT COSTS

Several studies have attempted to quantify costs of IROPS in terms of lost revenue or profitability to the airline experiencing the disruption. In 2014, the operations analytics firm masFlight aggregated a composite table of costs, as shown in Figure 1 on the right. The methodologies for calculating the costs vary quite a bit; however, the composite estimate of $8,995 or about $75 per passenger (calculated as a linear average of the six individual estimates) seems reasonable despite the large variance between the smallest and largest estimates.

The hard costs are relatively straightforward to calculate, consisting of three major components: (1) variable costs of flight operations, (2) passenger delay costs such as hotel and meal vouchers or staff overtime, and (3) revenue lost, either because the passenger cancelled the trip or rebooked on another airline.

A critical additional component of the cost of a disruption is the soft cost, or the cost of the pain inflicted on the customer because the flight(s) did not go as promised. This cost translates to the airline in the form of a loss of future business from that customer due to the impact of the disruption. The longer the delay experienced by the

## Figure 1: Estimates of Lost Value from a Cancelled Flight


*From Joshua Marks, "Updating Airline Cancellation Costs and Customer Disruption", presented at AGIFORS Annual Symposium, 2014*

customer in reaching final destination, the higher the soft cost. The important metric is the customer's delay, not the airline's. Thus, a relatively minor 30-minute flight delay that results in a customer missing a connection might actually result in a 6-hour delay in the customer reaching their destination. The variances in estimates of flight value shown in Figure 1 are mainly based on the assessed value of the soft costs.

Evidence from a study conducted by a major Asia/Pacific airline suggests that this component of IROPS may have several times the value of the hard costs of the disruption. The airline looked at a pool of frequent travellers over a one-year period. In the first six months, they divided the pool into two equal groups based on whether each traveller had experienced above average or below average disruption. Then they looked at the differences in revenue each group generated over the subsequent six-month period. The more disrupted group showed a drop in business relative to the less disrupted group. On a per-passenger basis, the observed drop in future business was several times the level of hard costs incurred in the course of resolving the disruption.

While an overall estimate might be useful as part of a business case for justifying development work on IROPS solutions, it is not usable for developing real-time mitigation solutions because the true cost of a delayed or cancelled flight will vary according to the circumstances. For example, consider the two scenarios shown in Table 2 on the right. In the "Low Value" columns, if Flight A is cancelled, its passengers have another flight to the same city, on the same airline, departing only half an hour later (Flight B), with enough capacity to accommodate all the passengers from Flight A. On the other hand, if Flight B is already full, as is the case for the columns labelled "High Value", then everyone on Flight A will be stranded overnight and will have to be re-accommodated the next day on a different airline, which is much more expensive. Flights are more valuable when the airline has few re-accommodation options; they are less valuable when there are ample ways to rebook the passengers on the same airline shortly after the cancellation.

While it is common to downplay or even ignore soft costs in analysing performance or developing a business case, this example illustrates that the soft costs represent an important – if not dominant – component of the cost. To ignore them because they are difficult to quantify is to

Table 2: Variation of Value in Cancelled Flights

| | Low Value | | High Value | |
|---|---|---|---|---|
| | Operate Flight | Cancel Flight | Operate Flight | Cancel Flight |
| **Flight A: LHR 1800 CDG 2030** | | | | |
| Booked: 80 passengers @ €200/psgr | € 16,000 | € 0 | € 16,000 | € 0 |
| Operating cost: 1.5 hours @ €6000/hr | -€ 9,000 | € 0 | -€ 9,000 | € 0 |
| **Flight B: LHR 1830 CDG 2100** | | | | |
| Booked: 70 passengers @ €200/psgr | € 14,000 | € 30,000 | € 14,000 | € 14,000 |
| Operating cost: 1.5 hours @ €6000/hr | -€ 9,000 | -€ 9,000 | -€ 9,000 | -€ 9,000 |
| **Soft Cost** (based on passenger delay value of €30/hr) | € 0 | -€ 9,000 | € 0 | -€ 9,000 |
| **Total Value** | € 12,000 | € 19,800 | € 12,000 | -€ 13,000 |
| **Net Value of Operating Flight A** (vs. cancel) | -€ 7,800 | | € 25,000 | |

assume they are zero, and that is most certainly not the right number to use.

## 3.2. MEASURES OF SUCCESS / METRICS

How do we know whether we have done a "good job" in recovering from an IROPS problem? There needs to be one or more metrics (ideally, only one) that allow airline executives to assess whether they are improving their IROPS mitigation methodologies over time. Many metrics are possible, including:

- Time required for all passengers to be re-accommodated
- Time required to develop a plan of cancellations and delays that will restore aircraft flow
- Airline operates 100% on schedule as soon as the weather clears and/or the cause of the disruption has been resolved; schedule integrity is restored
- Number of cancellations and total delays
- A comparison of passenger revenue that was received from other airlines (as a result of their disruption) with revenue given to other airlines (as a result of our disruption)

While each of these metrics is important, each tells only part of the story. In order to objectively compare alternative solutions to an IROPS problem, it is necessary to convert any desirable or undesirable attributes of each solution to a cost function. One solution is "better" than another if it has a lower cost. In theory, if two solutions have identical costs and the costs are accurately calculated, it should make no difference which solution is chosen, even though one might be good for Department A but not B, while the other is better for B than A.

The cost function serves as the composite metric that can be used to evaluate the impact of an IROPS situation. Corporate Finance departments at airlines could use this to set standards for operational performance and, ultimately, budgets. However, the complexity of the function, together with the need to make exceptions for unusual situations (a common problem in managing airline operations) means that few, if any, airlines are in a position to say how much IROPS problems cost them in the last quarter or last year. Without some measurement that is accepted at the corporate level, it becomes very difficult to create a

business case for new development to address a problem that is difficult to measure. This problem has had the effect of weakening the justification for pursuing IROPS solutions relative to all other possible corporate projects.

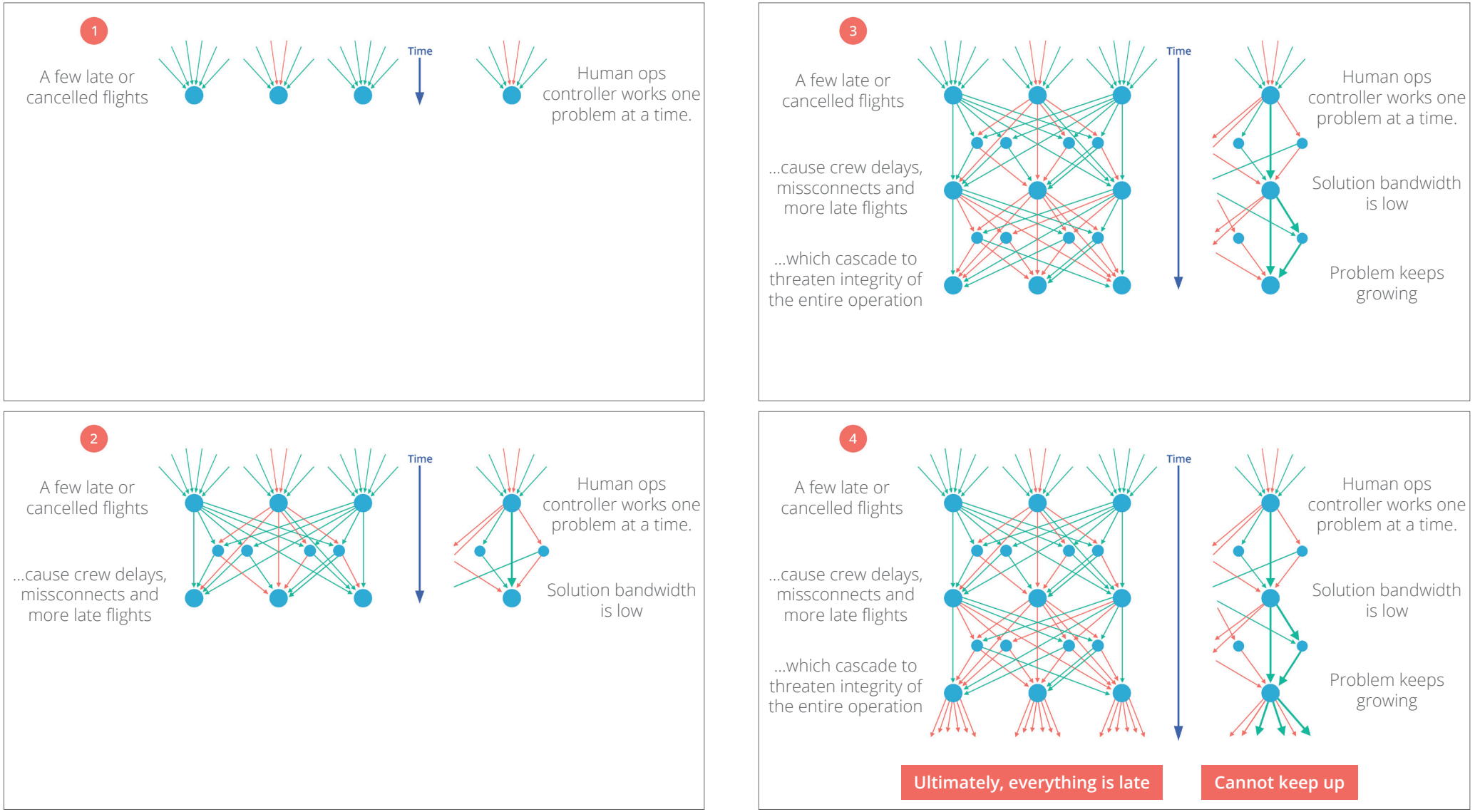
## 3.3. LIMITED HUMAN BANDWIDTH

Airlines have had computer support for managing their operations since the 1970s. Until recently, however, that support was limited to informing human managers where their resources were physically located and what those resources were doing (or planned to be doing) at a particular time. Decisions were made by managers exercising judgment. Human beings are very flexible decision makers, and they can quickly key on the most important factors that will have a bearing on the decision that needs to be made. However, they cannot process a large quantity of data all at once. Fundamentally, human judgment is very flexible in its approach to managing airline operations, but it is not a scalable process.

Human bandwidth limitations become a big problem for a large disruption, because human controllers can only work a small subset of the problem at any given time. If the disruption is relatively small, the operations controller can focus on repairing the aircraft itineraries to restore balance to the operating schedule (i.e., all aircraft positioned properly to operate the remaining schedule). In these cases, disruption is limited to a few flights and the passengers on them; once the passengers have been re-accommodated, the problem is solved. But there is a tipping point: if the disruption affects enough aircraft and passengers, the operations controllers will not be able to keep up, and the impact of the disruption will tend to spiral out of control. This is the IROPS problem for which automated solutions are necessary.

This is illustrated by Figure 3 on the next page, which shows the progression where a few late or cancelled flights cascade into a big mess. Green arrows represent flights that can go on-time; red arrows represent cancellations or large delays. When a disruption is small, the controllers can fix problems one at a time successfully. However, when it is large, the rate at which red arrows are turned into green is less than the rate at which unaddressed red arrows multiply as the day goes on. The only reason they are ever able to catch up is that operations decline sharply after about 9:00 PM and do not resume a normal level until about 6:30 AM the next morning.

## Figure 3: Why Airline Operations Control Problems Expand Virally



Adding to the overall complexity is the problem that it is usually very difficult to divide the work among several operations controllers, because each repair action taken affects other flights within the system. Dividing the workload by fleet type is usually feasible, but the larger fleets will still have a heavy workload that cannot be effectively divided.

## 3.4. SYSTEMS INTEGRATION

When systems are upgraded or replaced, new data sources must usually be integrated into the existing infrastructure. Much of it may need to be updated in real-time. The new data adds to the infrastructure that must be maintained for both the existing applications and the new ones. For an IROPS mitigation system, system integration represented a major component of the expense.

Until recently, this was a daunting problem. Internal airline IT departments would work closely with vendors to create the data bridges needed to satisfy the requirements of the upgraded system. Typically, there would be legacy systems that would need to interface with the new or upgraded system as well. The cost of porting data or making it compatible with a new entity was a significant fraction of the total life-cycle cost.

Integration methods and tools have now improved to the point where these problems are not quite so difficult; swapping a legacy system for a modern one no longer requires a "brain transplant" level of expertise. To be sure, it still requires careful planning to scope out all the improvements needed and to organise the implementation activities. The costs of managing the integration and cutover of an IROPS system are still significant, but they are no longer the showstopper they were a decade ago.

## 3.5. ORGANISATIONAL ISSUES

A serious obstacle to the development of IROPS mitigation tools and systems has been the general lack of senior management involvement and support. As described in section 3.2, creating metrics for measuring operational performance can be quite a difficult challenge, and vital for making progress toward solutions for IROPS. Without a set of metrics that can be tracked at a corporate level, managers have little or no basis for showing quantifiable improvements in the operation. Everyone can agree that

IROPS is a problem, but specifying solution methodologies that can show documented improved performance is a major challenge all by itself.

Furthermore, the nature of IROPS is that there are many constituencies within the airline, each with different goals and different metrics for tracking progress, and they may be conflicting. For example, Revenue Management will want to maximise revenue, while airports will be more interested in minimising passenger handling costs. Often, the best solution to an IROPS situation will be the solution that improves one metric at the expense of another.

When there is a need to rebook disrupted passengers to other airlines, there is the further issue that there are no standards for mass rebooking from one airline to another – it has to be done one booking at a time. While this by itself might not be a difficult problem to solve, it is symptomatic of many such electronic communications needs between airlines and their suppliers and partners, which will have to be addressed. This will drive the needs for standards and protocols to facilitate such communications, which will take some time to develop.

The net of these problems is that the operations controllers, who are responsible for stitching together the broken pieces of aircraft and crew itineraries to put the airline back together, do not have the tools or the time to check multiple possible solutions and pick the best one. Even if they did, they do not have a rigorous set of metrics that would tell them how well they are doing and provide clues on how to drive the metrics higher over time. As was pointed out earlier, the business case for doing anything will be weak without such metrics. Any proposed IROPS mitigation initiative will have little chance of attracting senior management support or funding, especially when compared with marketplace initiatives that have a much more tangible and immediate impact on corporate performance.

## 4. RECENT DEVELOPMENTS—AND PROGRESS

Following roughly a 20-year period of sparse investment and innovation in Airline Operations systems (and IROPS tools in particular), an increase in activity began around 2010. At first, there was little impact on IROPS development projects, due to the obstacles previously outlined in Section 3 (e.g., lack of accepted metrics, lack of senior management support). Instead, the bulk of the activity was directed toward systems that could accommodate sales of ancillary services such as baggage checking or seat upgrades.

As this unbundling of the airline product progressed, airlines found they could improve their revenue stream without increasing costs very much. Industry executives soon realised that maximising the value of the ancillary services was dependent on being able to deliver them reliably. This factor stimulated investments in Operations systems in general, which in turn helped the vendor community develop some new capabilities. The trend had the feeling of a Renaissance, or enlightenment, in that it followed a 20-year period (the "Dark Ages") where there was not much new capability development at all.

Because of this trend, there was a significant halo effect on IROPS development activities, as these were on the fringes of the ancillary revenues movement. For example, if a customer purchased a seat upgrade offering extra legroom and the flight was subsequently cancelled, it made sense to rebook the customer on a flight having a seat with that extra legroom if possible; otherwise, the revenue for the ancillary service would have to be refunded and the customer would very likely be unhappy. Vendors have now developed several passenger re-accommodation solutions, which represent a significant class of IROPS mitigation tools. Passenger re-accommodation tools also can address the broader problem of giving preferential service to the highest revenue customers.

This is a good example of why the obstacles mentioned in Section 3, which have made the IROPS problem historically difficult to address in the past, are now diminishing in importance and will become non-issues over the next several years. In turn, that has helped create an environment of entrepreneurial innovation in Airline Operations systems in general, but particularly for IROPS tools. We expect that these tools will come into more widespread use in the coming decade, and they will lay the groundwork for more sophisticated solution suites that will go after the heart of the IROPS problem – and eventually solve it.

Given the good start that has occurred over the last several years, we expect that progress will come at a brisk pace, but also in an evolutionary way. We have observed some patterns in the solutions developed thus far, where each successful innovation becomes the baseline for the next set of innovations built on top of what has already been accomplished.

## 4.1. IROPS DEVELOPMENT DOMAINS

Because the airline IROPS problem has such a broad scope, the first solutions will address only a manageable subset of it. The remaining parts of the problem will remain static: i.e., they either will be addressed through separate tools or resolved manually using human judgment, just as they were before computer-aided tools became available.

To date, the tools that have been made available in the marketplace or developed internally by airlines for their own use have attacked the IROPS problem in one of three repair domains, each with its own set of functional and IT challenges:

- Aircraft Rerouting – Typically, the first symptom of an IROPS event is that one or more flights will not be able to proceed as planned. If the cause is a weather event affecting multiple flights, then downstream operations will likely be affected as well. Operations controllers must restore aircraft flow, so that all operating flights have an aircraft assigned and that aircraft are in position to support a 100% operation as soon as possible after the weather clears. This requires surgically reconnecting future flights with available aircraft.
- Crew Trip Repair – This is the same problem as aircraft, except that the legality rules for crew are much more complicated than they are for aircraft. Crew do not always follow the aircraft, and finding a crew solution often necessitates swapping assignments with a fresh crew. Sometimes, no crew can position in time to take an open trip, a situation that will require further delays and/or cancellations to resolve.
- Passenger Re-accommodation – If a passenger's flight is cancelled or delayed long enough that they cannot make a planned connection, then that passenger must be rebooked on some other flight or combination of flights to reach their destination. The re-accommodation can be done at any time, but will be much more effective once the major aircraft dislocations have been fixed.

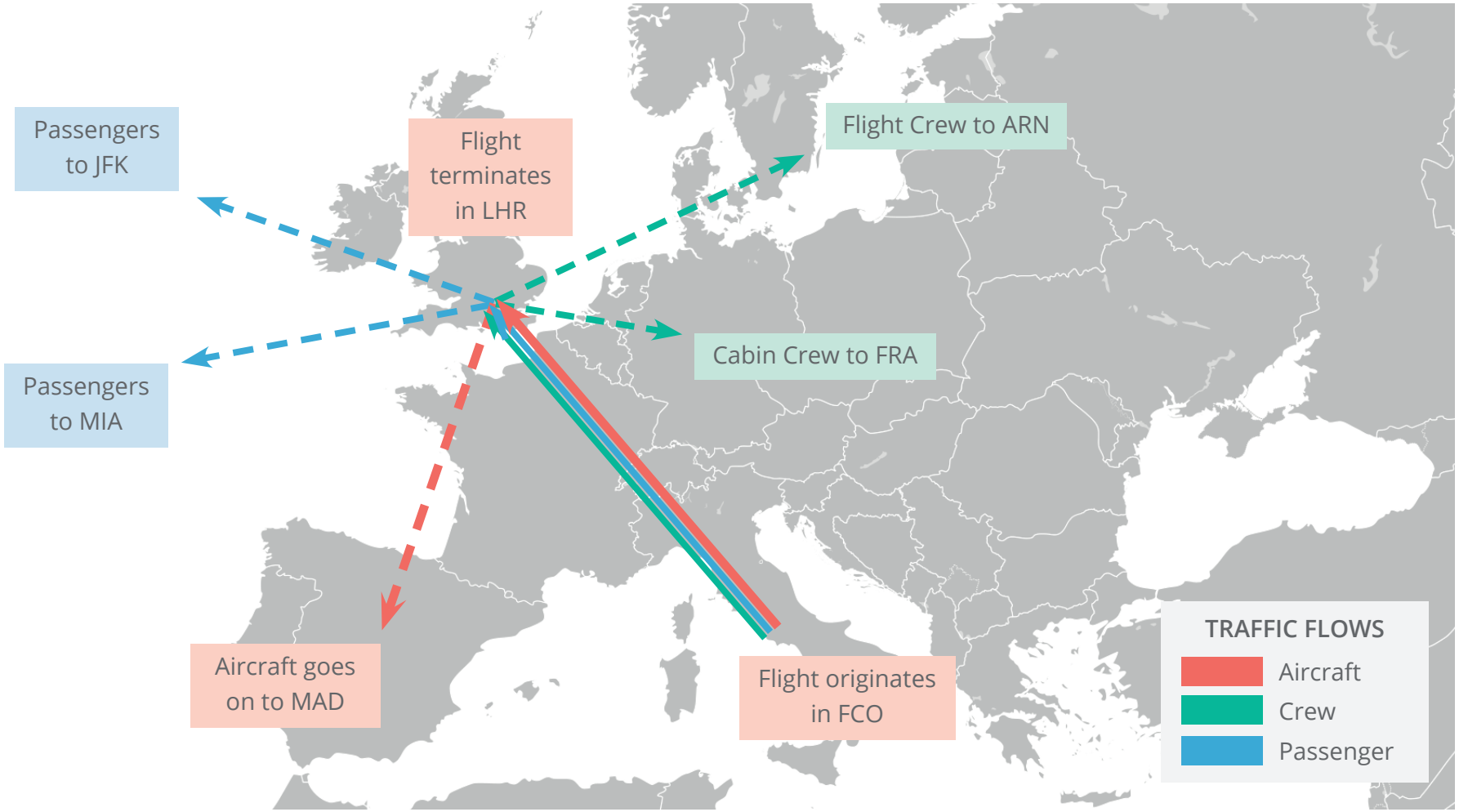
The key problem in rebuilding the aircraft routings, crew trips, and passenger itineraries is that they are only rarely going on the same itineraries. As shown in Figure 4 on the next page, the flight from Rome to London is carrying everyone on the flight between FCO and LHR. However, the flight crew is going on to Stockholm (ARN) and the cabin crew to Frankfurt (FRA). Some passengers are completing their trips in LHR; others are going on to JFK or MIA. The aircraft itself is proceeding to Madrid (MAD). There can be dozens of itineraries for passengers, crew, and aircraft, most of which will be in some need of repair when a flight is cancelled or significantly delayed.

Solving the aircraft and crew problems simultaneously would be very useful . Unfortunately, the mathematical challenges involved in finding a composite solution in one combined step seem insurmountable at the present time. Most airlines resolve the aircraft routings first, then rebuild their crew trips and re-accommodate passengers based on the new set of routings. If there is no crew solution available for a given aircraft situation, then the operations controllers have the option either to rerun the aircraft solution to eliminate whatever flaw caused the crew problem, or treat the flight(s) not having a crew as an additional IROPS event that can be fixed separately.

Passenger re-accommodation tools may be used to move customers from their broken trips to new itineraries involving good trips, and are valid whether aircraft and crews have been rerouted or not. However, the re-accommodation process will be much more effective if the aircraft routing changes have already been implemented, as the newly-built flights will usually provide more re-accommodation options. It is not necessary to include passenger rebooking information in the optimisation of the aircraft routings, as long as the re-accommodation assumptions are consistent with the applications that actually move the reservation records.

Besides the technical difficulties in optimising multiple domains simultaneously, it is probably not necessary to do so to achieve significant improvements in IROPS handling. For the foreseeable future, therefore, airlines and vendors should not try to develop composite solutions that span multiple domains. Instead, they should focus on each area individually and look for procedural ways to ensure that the solutions mesh.

Figure 4: Traffic Flows on a Typical Flight



## 4.2. LOOK-AHEAD CAPABILITY

Full IROPS recovery capability will require an additional module that is separate from aircraft, crew, and passenger optimisation. This tool will project the knock-on effects of delays and cancellations that have already been recorded. It will be critical for assessing whether the actions taken by the operations controllers or recommended by the optimisation modules are "enough" to bring the airline back on schedule .

Fundamentally, the Look-Ahead capability is a simulation of airline operations for the remainder of the operating day plus the next day. The simulation records a departure when aircraft, crew, and connecting passengers are all available and ready from their previous flights; this could be an on-time departure or a long delay, depending on what happened earlier in the day's operation. The Look-Ahead system becomes a forecasting tool that can pinpoint inevitable delays later in the day, based on the operations that have already occurred. As Figure 3 showed graphically, comparatively small problems that are left "untreated" can multiply into major disruptions, with systemwide impact.

## 4.3. INTERACTIVE VS. AUTOMATED TOOLS

The IROPS mitigation tools that have been built thus far fall into two major classes of capability:

- Interactive tools will generate a local solution to an IROPS problem. They will help solve a piece of the problem by identifying resources that could be brought in to substitute for the resource that is late or otherwise unavailable. Fundamentally, interactive solutions leave the decision process with the controller. They do not resolve the loose ends that result from reassigning aircraft or crews one at a time, but the controller can work on the loose ends sequentially until they are all fixed.

- Automated tools will perform a large-scale optimisation that addresses a large number of resource issues or constraints simultaneously. They are much better than interactive in working out all the details and complexities of the solution, but they are more expensive to build, more difficult to use, require more training, and often cannot handle one or more key constraints.

While the automated tools offer more potential for creating complete, minimum-cost solutions, a push-button environment can only offer an all-or-nothing answer; i.e., if the automated solution is not workable for some reason that is unknown to the optimisation software and unique to the situation being addressed, the offered solution is essentially useless.

Airlines seem to prefer interactive solutions for their first foray into IROPS mitigation tools, mainly because they represent an extension to the manual processes the controllers are accustomed to using. Interactive tools will guide the operations controllers to arrive at a faster answer at lower cost, often by using analytics or artificial intelligence methods to rank order possibilities. Such tools will produce significant value over and above a purely manual operation. Most importantly, perhaps, the controller group will be able to understand and quickly evaluate the answers they get from the tools, which will raise the overall performance levels as well as encourage development of more complex solution methodologies over time.

Despite their utility, the interactive tools will eventually become unsatisfying due to their limited scope, and the automated tools/systems will be used more frequently. The automated tools will never be able to completely mitigate the all-or-nothing nature of their solutions, but as the tools gain more features to allow the controllers to direct the solution development, their results will improve to the point where they become the dominant methodology.

## 4.4. CURRENT STATE-OF-THE-ART AND SOLUTIONS MARKETPLACE

Airlines around the world began to embrace the hub-and-spoke concept in the 1980s. By providing a wider scope of connection opportunities for airline customers, airlines managed to drive revenues and profits higher. But they also increased the complexity of their operations in ways that magnified the impact of weather events and other large-scale disruptions at their largest hubs.

Beginning in the 1990s and continuing into the 2000s, the academic community conducted research on IROPS mitigation solutions, most of which were based on operations research optimisation techniques, such as linear programming and network optimisation. Airlines did relatively little, mainly because of the inherent problems described in Section 3. Prototype models showed

promising potential, with significant savings demonstrated when the models were run after-the-fact, in a laboratory environment. Meanwhile, advances in optimisation techniques, together with general improvements in computing power and cost, combined to improve performance of these prototypes to the point where they were ready for testing in an actual airline environment.

Caleb Technologies (now part of GE Aviation) was the first start-up firm founded for the explicit purpose of addressing the airline IROPS problem. It moved the IROPS mitigation processes from a research environment to a development mode. During the 2000s, several traditional airline IT vendors began offering solutions as well, based on similar mathematical formulations to the 1990s prototypes in the academic literature.

Table 5 on the next page shows the vendors currently offering software products that address IROPS issues to some degree. As the table shows, there are a number of solutions available, and there are likely to be other products not on the list in the final stages of development, which will become part of Table 4 shortly. At this point, the passenger re-accommodation tools are the most highly developed, with several products offered for sale; most of these allow passengers to interact with the solution via their smartphones. However, the fact that none of the products in the Table is generating noticeable "buzz" within the industry suggests that the market for IROPS solutions is still immature. Nevertheless, there is interest and attention from airlines, with activity and investment going on at meaningful levels. As a result, much additional progress can be expected over the next several years.

## Table 5: Current IROPS Vendor Product Offerings

| Function | Amadeus | GE Aviation | HP | IBIS | Jeppesen | Lufthansa Systems | Sabre Airline Solutions | SITA |
|---|---|---|---|---|---|---|---|---|
| Look-Ahead Capability | ✓ | | | ✓ | ✓ | | ✓ | |
| Rebuild Aircraft Routings | ✓ | ✓ | | | ✓ | ✓ | ✓ | |
| Crew Recovery | | ✓ | | | ✓ | ✓ | ✓ | |
| Passenger Rebooking | ✓ | | ✓ | | ✓ | | ✓ | ✓ |

## 5. LOOKING FORWARD

Airline operations systems have been going through a kind of Renaissance, or reawakening, since about 2010. The manifestations have been in the form of corporate attention to operational issues (including IROPS) and increased investment in systems, driven by the need to support revenues from ancillary services such as bag check fees. The Renaissance follows a 20-year period of relatively low investment in operations systems (1990-2010).

Several other favourable factors – unrelated to IROPS – have further stimulated this trend:

- Airline customers are demanding faster, more transparent responses to operational problems. For example, if a flight is cancelled, travellers expect to receive rebooking options on their mobile phones.
- Through nearly instantaneous communication, social media spreads the word about operational problems quickly and effectively. This magnifies the impact of those problems on future booking patterns, and ultimately future revenues. In effect, this amplifies the benefit of a mitigating solution and therefore helps the business case for development.
- Investment capital is available at low interest rates.
- Recent good airline profitability has helped to pull airline executives away from a short-term focus on cost-cutting, which had long since become unproductive.
- IT environments have become more fluid, reducing the cost and risk of major system implementation and cutover.

The net result of these trends and supporting factors is that near-term progress toward meaningful IROPS mitigation systems and processes is almost inevitable. The only real question is how fast progress will come.

### 5.1. EVOLUTION OF IROPS CAPABILITIES

For all practical purposes, development of IROPS response capabilities will be similar to building a new tech industry from the ground up.

Capability development has already started through entrepreneurial initiatives to build prototype tools. The oldest of these date from the 1990s and addressed small parts of the IROPS problem, but never got any market

traction. However, they did lay the groundwork for more recent developments, which include some real product offerings from some of the airline industry's leading systems providers.

In addition, some large airlines have launched internal projects to build solutions for their own use. The scope of such tools is mostly unknown (since those airlines are understandably reluctant to discuss what may be a real competitive advantage). While we do not believe that any have (yet) progressed to the point where other airlines have expressed interest in licensing them or in performing similar development, we believe that event is likely to be not far off.

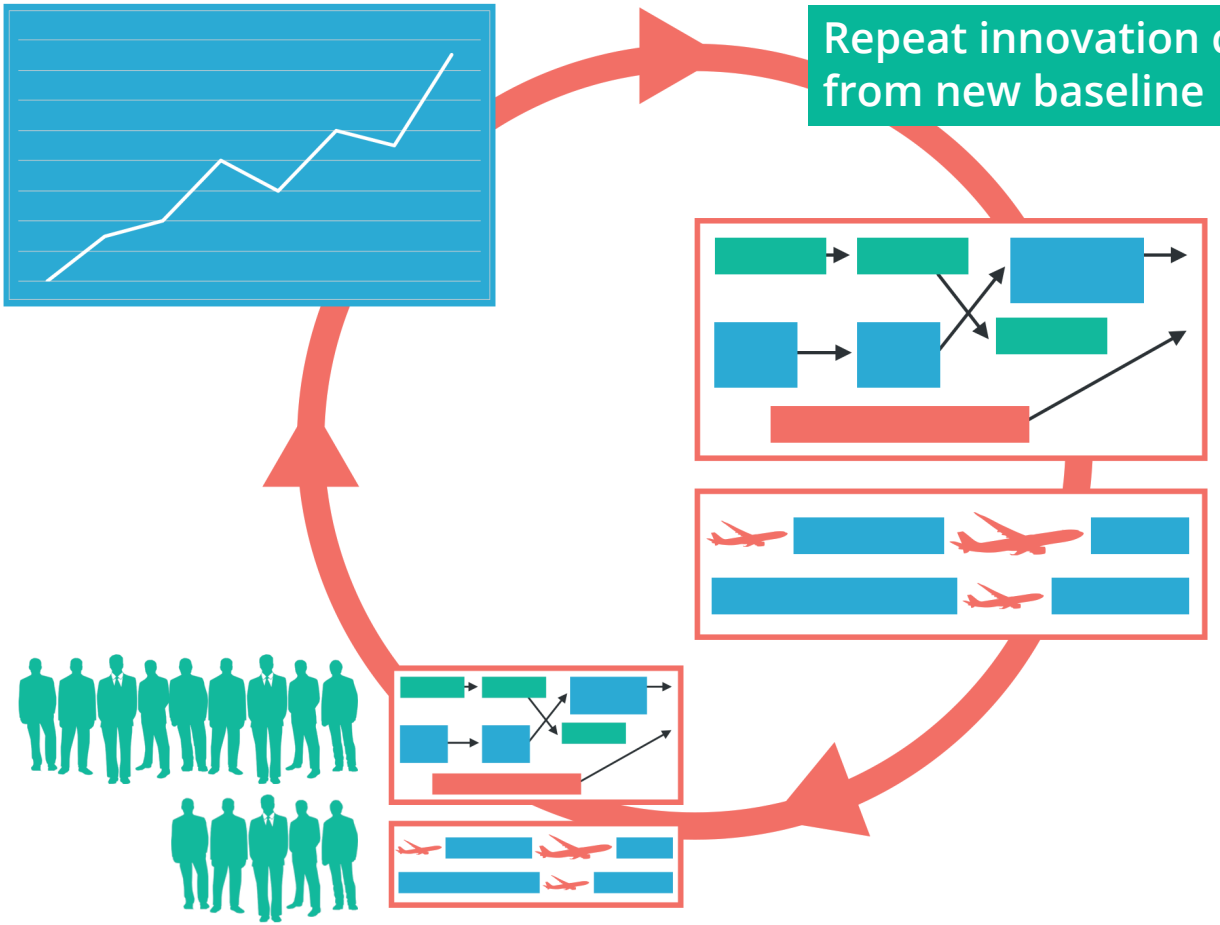
The paradigm for innovation is likely to follow a path similar to the one illustrated in Figure 6 on the right:

- Entrepreneurial initiatives at airlines or vendors will create prototype solutions. These prototypes will solve small parts of the problem, adding value.
- Solutions will attract followers. Some will attract more than others will.
- Leading solutions will generate ideas for further capabilities, which will start another improvement cycle.
- Solutions will improve both horizontally (solving larger and more comprehensive pieces of the overall problem) and vertically (performing an existing function better), both of which provide value and sustain the improvement cycle.
- Eventually, deep capabilities will emerge.

As the scope of solutions grows over time, there will be an increasing need to coordinate activities with upstream/downstream partner entities. After all, every airline trip is taken in order to accomplish something on the ground, at a place far from home. As IROPS solutions become more sophisticated, airlines will want to coordinate their actions with those of hotels, event managers, and other service providers at destination. Airlines should be the main driver, since air travel maintains contact with the traveller throughout the trip (and is also the means to accomplishing the mission of the trip). Airlines will want to share data on service problems, consistent with the regulatory rules that protect passenger data from unwanted use. Over a period of time, it will be possible to better coordinate solutions so that the airline IROPS

## Figure 6: Continuous Improvement/Innovation Cycle for IROPS Solutions

**SUCCESSFUL SOLUTIONS WILL ADD VALUE**
as reduced cost, increased revenue and better customer service




**DEVELOP PROTOTYPE SOLUTIONS**
solving some small part of the overall problem

**SOLUTIONS WILL ATTRACT FOLLOWERS**
some more than others

response will be known to the ground service providers, who can adjust their resource deployments accordingly.

As discussed earlier, this progression of increasing capabilities looks remarkably similar to the development of the smartphone market a decade ago. In 2005, downloading emails to a phone was well established, but one could not do much more than read them; attachments that were not pure text files generally could not be viewed. Very few phones had keypads. Accessing the Internet was slow and painful, with few tools supporting it. The concept of phone apps did not exist.

The release of the first iPhone in 2007 and Android phones shortly thereafter solved most of these problems. It did not take too long to fill in the remaining holes of reading email attachments and accessing the Internet. More bandwidth largely solved the slow speed problem. The growing availability of specialized apps – including voice recognition – facilitated using the phone as a stand-alone personal device.

Other airline functions – including fleet assignment, crew planning/scheduling, and revenue management – have followed a similar pattern. First, some islands of automation develop, and then these get refined. Capabilities grow horizontally. Ultimately, a few "killer apps" encompass most of the problem and make it routine. Incremental improvements continue from there, eventually reaching a point where everyone is working on something else because of a lack of further improvement opportunities.

## 5.2. GUIDELINES FOR SUCCESSFUL SYSTEMS IMPLEMENTATION

If we take a step back and view IROPS development projects as components of a complex system implementation involving applications software, systems integration, database management, personnel training, continuous improvement processes, and executive oversight, then the implementation process is very different from that of a mature, proven system (e.g., corporate accounting). It requires a different management approach and mindset as well.

Fundamentally, any IROPS development and implementation project is a Research & Development project. This implies that favourable results are not guaranteed and may require several iterations of different methodologies and supporting technologies to achieve success. This is the nature of trying something new – it may

take a while to get it right, and there will be dead end paths explored along the way.

As with any new concept, user involvement is critical for success. This means that system users not only test new features to ensure that the correct results are produced, but also provide feedback on refinements that will improve future results. This will require that some staff time be allocated to non-production activities that improve future performance, but have no impact on today's airline. This is no different from professional athletes practising and preparing for obscure scenarios that might or might not ever come up in a game. "War games" and "practice sessions" are routine for athletes, but quite rare for airline operations personnel. This needs to change.

Support from airline senior management is also essential throughout the development and implementation processes. At most airlines, the Corporate Finance department is responsible for measuring routine activities and ensuring that they are conforming to the airline's best interests. If Finance is involved in capturing meaningful metrics from operations, assessing their bottom-line impact, and helping to drive them to higher levels, then senior management support is virtually assured. That will be an important factor for sustaining future IROPS improvement initiatives.

## 5.3. PROCESS MATURITY

Development of IROPS mitigation tools will be a work in process—it will never be "finished," but it will eventually lead to a state of continuous improvement, where each innovation builds on all the previous innovation. When the market reaches a state where there are few new ideas for how to improve things further, then investment will fall off. This has happened already for several key airline processes, including Crew Planning and Flight Scheduling, which are fairly mature and no longer evolving at a brisk pace.

However, given the current immature state of the market for IROPS solutions, that day is a long way off. Airlines and their systems suppliers are just beginning to make progress in breaking down the IROPS problem into manageable chunks that can be addressed one at a time, where each improvement builds on the previous improvements to add to the overall portfolio of recovery capabilities.

The data on IROPS costs show that there is a large block of value to be captured from better IROPS management, both in systems development and in procedures for managing the systems. Substantially all of that value is yet to be achieved. Someday, we may reach a point of diminishing returns, where investment declines because there is not enough financial return to support further development of IROPS management tools. But for now, the airlines and supporting industries that invest in the techniques that can go after the value can look forward to a number of productive years ahead.

We have reached the point where there is wide recognition – both inside and outside the airline industry – that IROPS has become an obstacle that will limit growth and profitability not only for airlines but also for the travel business in general. At the same time, there is much ongoing entrepreneurial activity, which is working to develop new automation solutions as well as enhance old ones. Airline operations managements see the value, and have now begun to align their staffs to exploit these new tools and technologies to create a more responsive environment throughout the value chain. Today, IROPS might be characterised as an unsolved problem. But with all the attention and investment it is getting, it is not going to stay unsolved very much longer.

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