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Airline Irregular Operations

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Introduction

What are irregular operations? Among the highest uncontrollable costs of running an airline, irregular operations involve the management of, and recovery from, disruptions, especially those caused by bad weather.

For a typical airline, irregular operations can cost as much as 2% to 3% of annual revenue. Proper planning for irregular operations and management of the recovery process can result in a cost reduction of at least 20%.

The problem, its causes and remedies are discussed in the following sections.

Disruption

A disruption occurs any time that flights are interrupted, i.e., diverted to an alternate airport, or where there are significant numbers of cancellations or delays. Either weather or maintenance can produce these problems. It potentially can take much longer to recover from an individual maintenance problem than from any weather disruptions. Yet, weather causes major irregular operations.

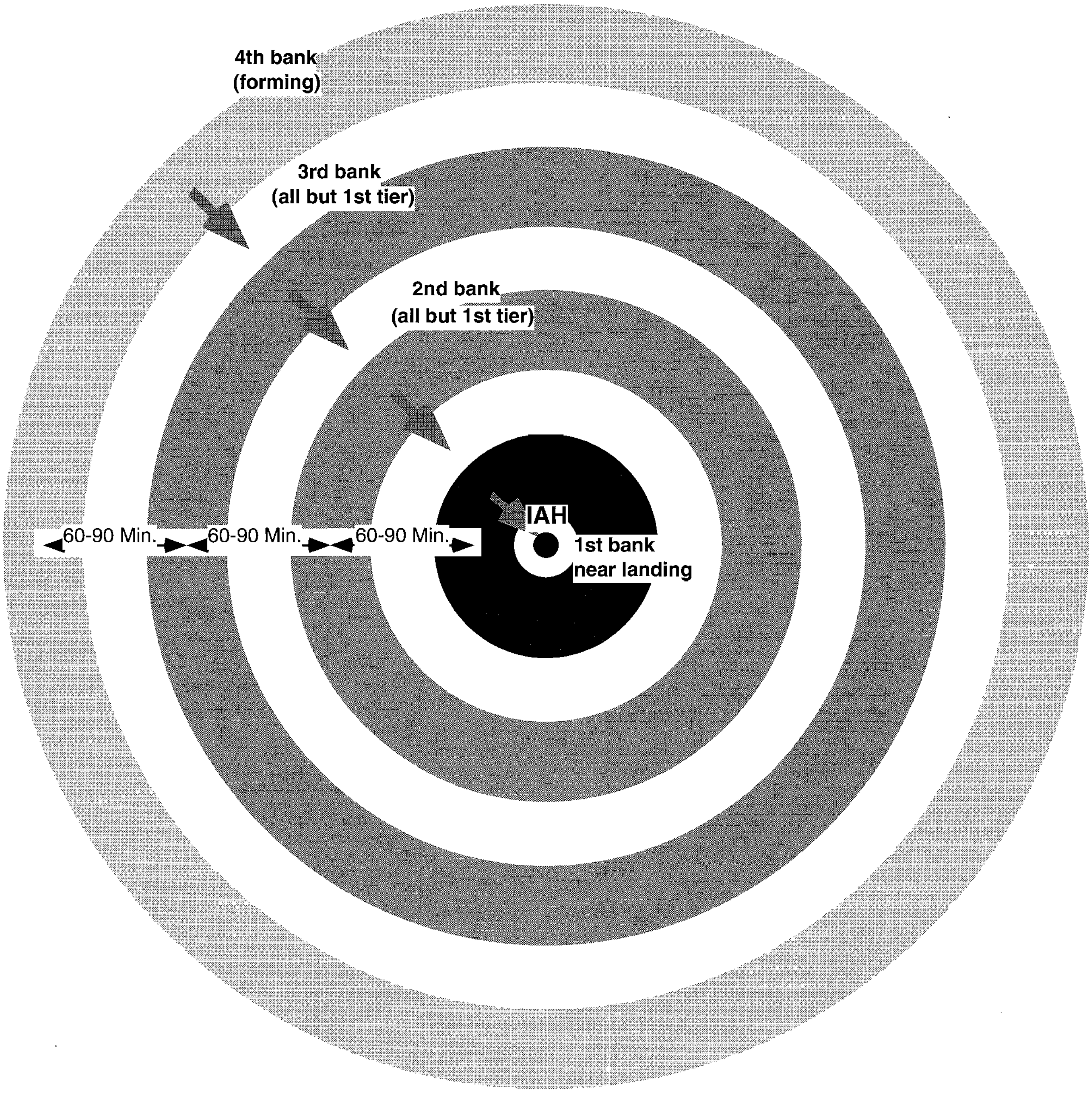
Analysis of a variety of different airlines, both large and small, has produced the following set of statistics:

- An average 0.1% to 0.2% of a typical airline's flights will be interrupted due to maintenance problems. As many as 5% to 10% of all flights could experience cancellations or delays due to maintenance problems.
- An equal average 0.1% to 0.2% of the same airline's flights will experience interrupted flights due to weather problems. As many as 10% to 20% of all flights could experience delays or cancellations due to weather.
- Cancellations from both causes can ultimately affect as many as 1% of all flights

So, why is the weather problem more severe overall, even though individual maintenance problems can be more costly per isolated flight? Two reasons:

- Maintenance problems are scattered randomly throughout the airline operation. Any airline is going to have a certain degree of slack resources. Much of the disruption caused by maintenance can be absorbed by the slack.

Figure 1. Typical Traffic Flow



- Weather problems are caused by thunderstorms, snow, fog, ice storms, etc.; these are concentrated, local events. These weather events result in some portion of the airline's operation being completely crippled. Any flight entering or leaving the crippled area will be affected.

Ultimately, the majority of an airline's problems in a weather-related irregular operation are not even directly caused by the weather, but are instead downline, or ruboff effects from the flights that were originally affected by the weather.

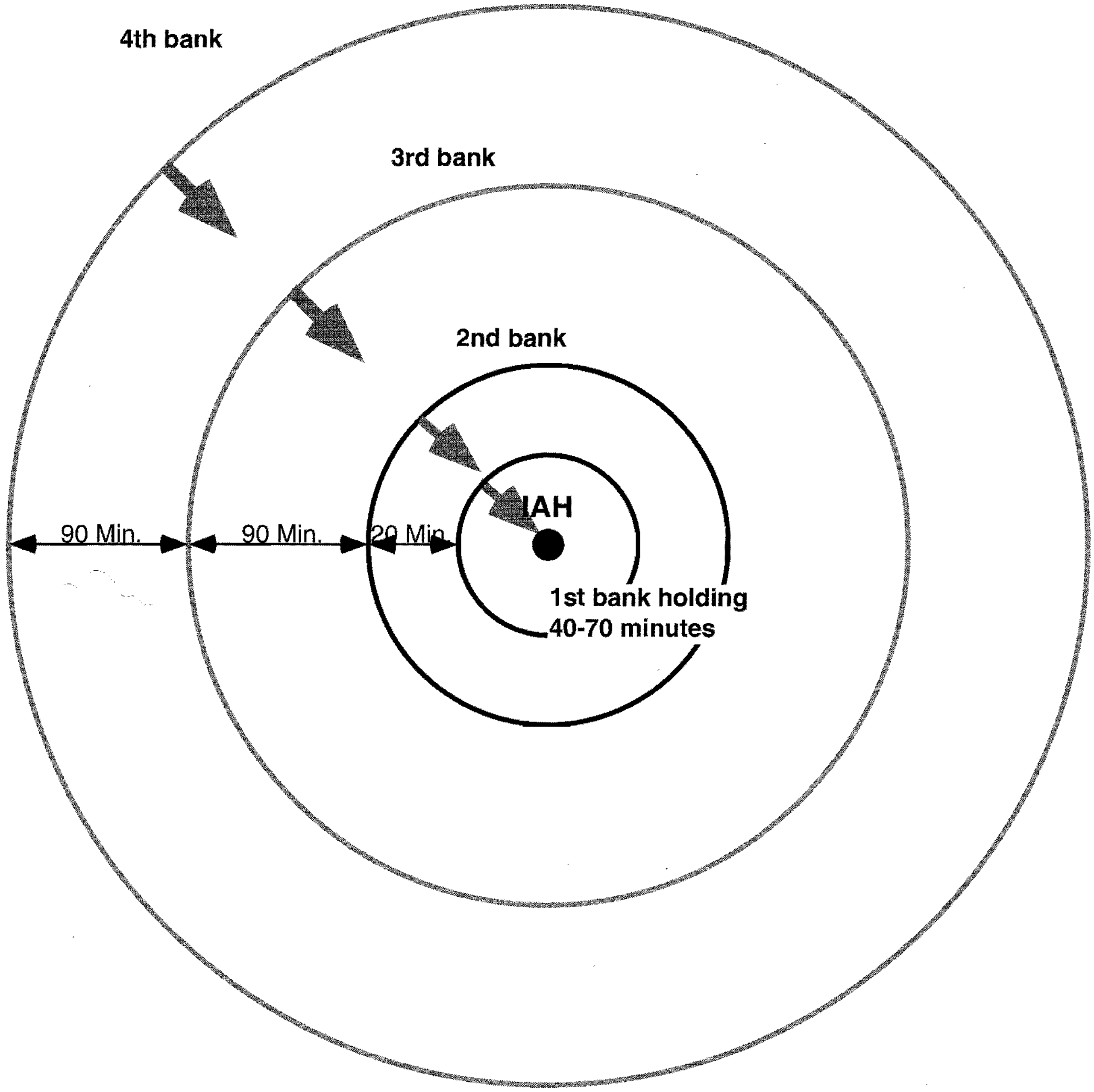
This results in a significant public relations problem for the airlines, often unfairly costing them additional lost revenue due to frequent conversations such as this:

Passenger: "Why is my flight [delayed two hours] [canceled]?"

Gate/ticket agent: "Because of the [snow] [thunderstorms] [fog] in [Atlanta] [Chicago] [Dallas] [Washington]."

Passenger (to himself): ("What an airline! That

Figure 2. After Weather Problem Has Begun



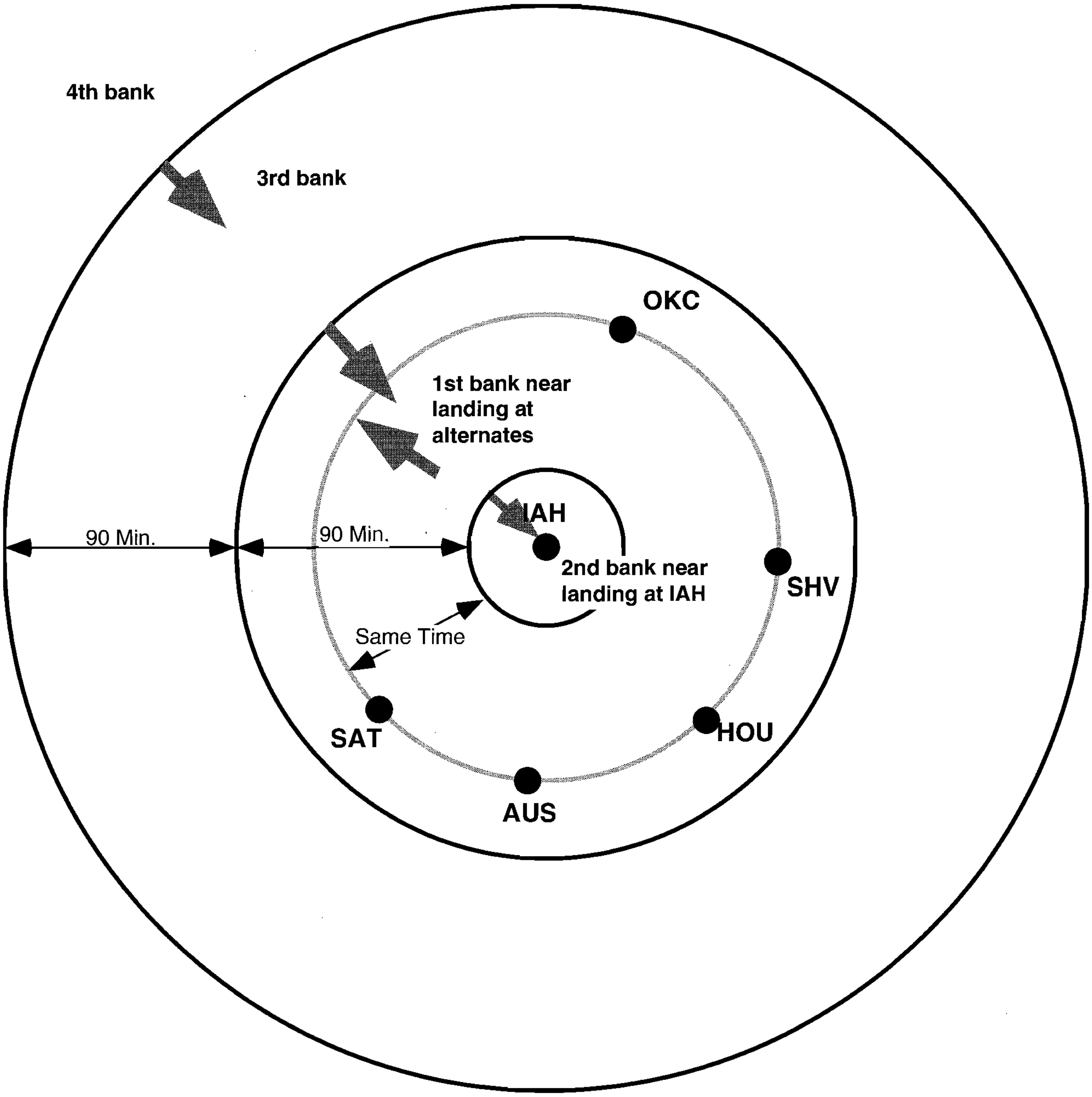
weather was this morning? Here I am in San Francisco waiting for a plane from Seattle! What does something that happened on the other side of the continent have to do with me? If they lie to me like that, I'll never fly them again!")

The Anatomy of an Irregular Operation

Most U.S. domestic and many overseas regional airlines operate hub-and-spoke systems, which greatly exacerbate the downline effects of any irregular operation. A point-to-point airline will produce fewer downline effects; however, recovery options from any problem tend to be more limited. Also, international point-to-point airlines still usually have a principal hub, which causes even more disruption to them when it goes down.

In a hub operating with arrival banks, the typical traffic flow will look like Figure 1, from a time/distance view. A bank is a group of flights scheduled to arrive together in order to maximize opportunities for con-

Figure 3. When Diverted Flights Land

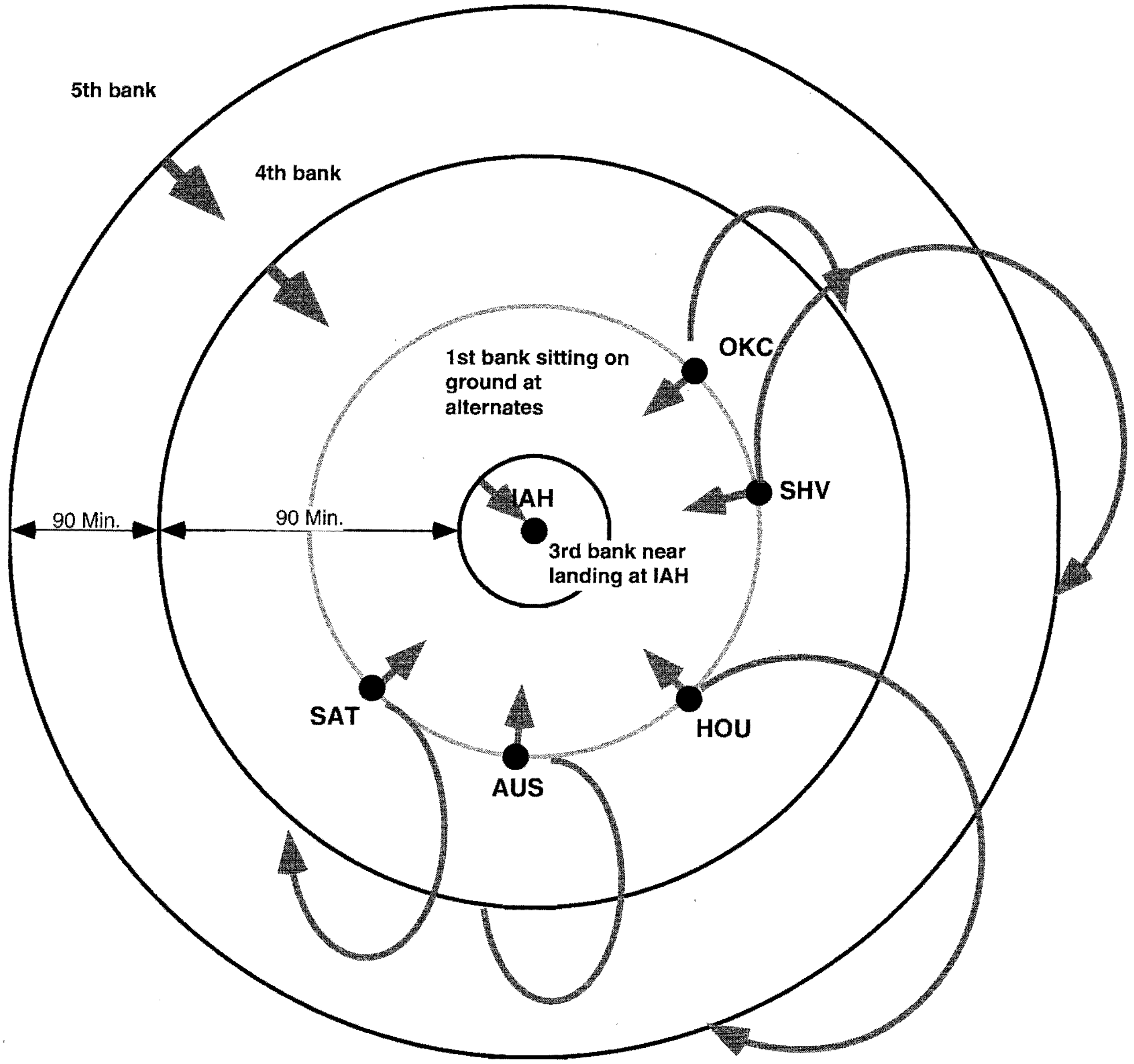


nections. In the irregular operation, the bank maximizes opportunity for disruption. Banks can be scheduled as close as about one hour apart — the minimum time to turn them around on the ground. In the diagram, the first tier refers to that group of cities closest to the hub. The first tier, cities 100-250 miles distant, are usually used as alternate airports.

Of course, the farther apart banks are spaced, the fewer the potential problems; but the more costly the hub operation. When the weather problem begins, the destination first operates with a reduced traffic flow, and eventually a closed airport. Now the view starts to look like Figure 2.

Everything will be fine if the airport resumes normal flow before the following bank arrives at the destination area, or before the bank holding near the destination uses up their holding fuel. However, time and or lack of fuel will produce a severe problem if the weather problem persists more than 60-90 minutes. With fog, ice, summer thunderstorms, or snow, it usu-

Figure 4. Typical Recovery—Inserting Flights Into Banks



ally does. The following now results — the bank that was holding is low enough on fuel that they divert, they interrupt their flight by flying to a new destination with better weather 100-200 miles from the original destination, perhaps 45 minutes flying time away.

Meanwhile, the bank that was following close behind arrives in the destination area with sufficient fuel to hold for 45-90 minutes, and usually has the opportunity to land at the destination.

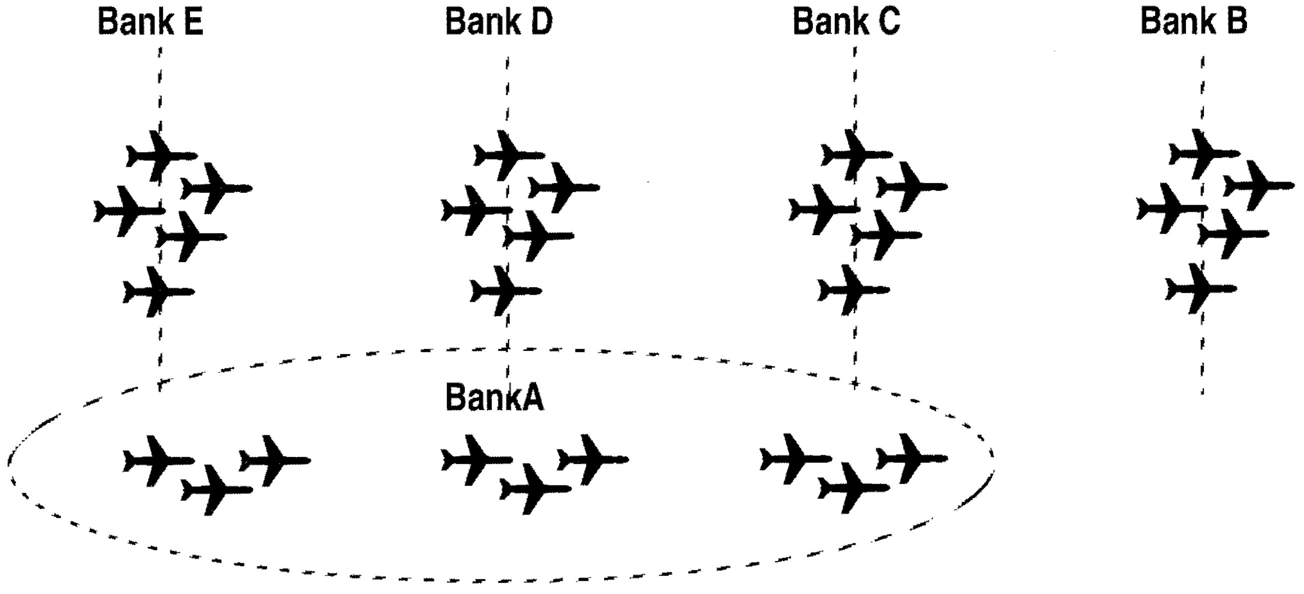
Unfortunately, the *second* bank is landing at the *original destination* at about the same time that the *first* bank is landing *150 miles away*! In a multiple diversion scenario, it now looks like Figure 3.

Now we have an irregular operation. Two banks are on the ground, scattered all over a region. But the planes are only 45 minutes away and the hub is open. So the airline can get back on track in an hour or so, right?

WRONG? The airline is now out of sequence. Just to get aircraft back to a hub will involve the following time factors, assuming the most common case of multiple diversions:

- 45-90 minutes: The original delay in holding.
- 45 minutes: Fly to alternate.
- 30-75 minutes: Refuel at alternate.

Figure 5. Typical Recovery—Feeding One Bank Back Into a Hub



- 30-60 minutes: Wait for new departure clearance to original destination. Remember, things are a mess. ATC is very busy! Also, the first tier ground stop exacerbates the problem.
- 45 minutes: Fly to original destination.
- 3 hours - 4 1/2 hours: *Minimum* total time factor.

So has the airline recovered? No, because all of those aircraft were supposed to be at new destinations by now, and also because there aren't enough gates, stands and other ground resources at the hub to handle double the normal throughput. So the recovery process looks like Figure 4.

This view accurately depicts the confusion that is occurring over time as diverted flights are integrated into successive banks. Looking at it from a view of banks over time, the airline now needs to recover the missing bank as in Figure 5. Both the timing issues and a shortage of gates in the hub will lead to this gradual recovery process.

Because of the missing 3-4 hours, recovery skips the first one or two banks. The actual recovery process will take a minimum of half a day, but can persist over a full day or more.

While this example focuses on diversions, the same problems result from extended cancellations of flights.

- The act of diversion recovery is really two separate jobs: (1) keeping the airline running; i.e. processing the current and next bank; and (2) planning initial diversion recovery, starting about two banks out.
- The act of diversion recovery is going to be constrained by several issues that will vary in particular situations. These are (1) a shortage of gates at the hub in each bank when processing multiple banks; (2) exact timing of the actual diversions will influence the degree of difficulty that will occur during recovery; (3) time remaining before crew rest requirements force personnel out; and (4) possible variable spacing of banks.
- The recovery process becomes constrained primarily by crew rest restrictions, crew availabilities and special mission aircraft (required for critical flights, and flights that must be flown with specific aircraft). In some airlines, segregation of the airline by route and airport by fleet produces a further constraint.

The mode of repairing the disruption caused by an irregular operation today requires that the following set of priorities (among others) be followed, usually in this order:

- Do whatever it takes to fly tomorrow's schedule.
- Fly today's mission-critical flights (critical for either marketing or system balance reasons).
- Bring aircraft back into balance.
- Bring crews back into balance.
- Get passengers to their destinations.

Balance refers to the concept of restoring resources to their proper schedule sequence, at a point where they can infinitely repeat their schedules.

Note that passengers are lowest on the list. This has to be the case to prevent tomorrow's problems from continuing to snowball off of today's problems. Only with Irregular Operations decision-support computer systems currently available at a few airlines, can the passengers be put at the top of the list, where they need to be to help the airline's revenue picture!

When the system is out of balance, the real job of recovery is the defense of the schedule (Beatty, Murthy, Miller and Sorenson, 1995). The sooner the schedule can be made to operate, the more quickly the passengers' needs can be met. Without computer systems to help with schedule recovery, there will be many more cancellations than might otherwise be necessary to produce either an operable (and smaller) schedule today or a normal schedule tomorrow.

Impacts and Costs

The irregular operation immediately produces costs far above the actual cost of the extra flying; and cancellation to reduce flying does not lower these costs. This is because the cost and disruption the airline experiences is caused by the flights being out of sequence, the resources being out of place, and the airline network, the system, being out of balance. Aircraft, crews and passengers are in the wrong cities. Many crews have exceeded their maximum duty day and are illegal to fly again.

Some of the basic impacts are:

- Multiple cancellations per diverted flight, to deal with airport congestion; missing crews and aircraft, to bring the system back into balance. These will not only be to the direct downline flights, but can be seemingly unrelated. An average of three cancellations per diversion was the result in one study.
- Often, a ferry flight or an overflight is necessary for each diverted flight.
- Significant increases in taxi-out and taxi-in times, due to ramp congestion resulting from the schedule disruption.
- In one study, as many as 50 flights were delayed for each diverted flight. As many as 15 to 20 flights are delayed per canceled flight in situations where there are no diversions.
- This can all result in several hundred passengers directly disrupted by the diverted flight, as well as thousands of passengers delayed. The resulting passenger loss of goodwill has a major impact on future revenue.

The impact to flying operations is shown in Figure 6. Note that the canceled and ferry flights may be at an airport not experiencing the weather causing the disruption.

Reducing the amount of disruption caused by an irregular operation can result in significant reductions in each of the following areas:

- Fuel costs.
- Aircraft operating costs.
- Lost revenue.

Figure 6. Direct Impacts of Diversions

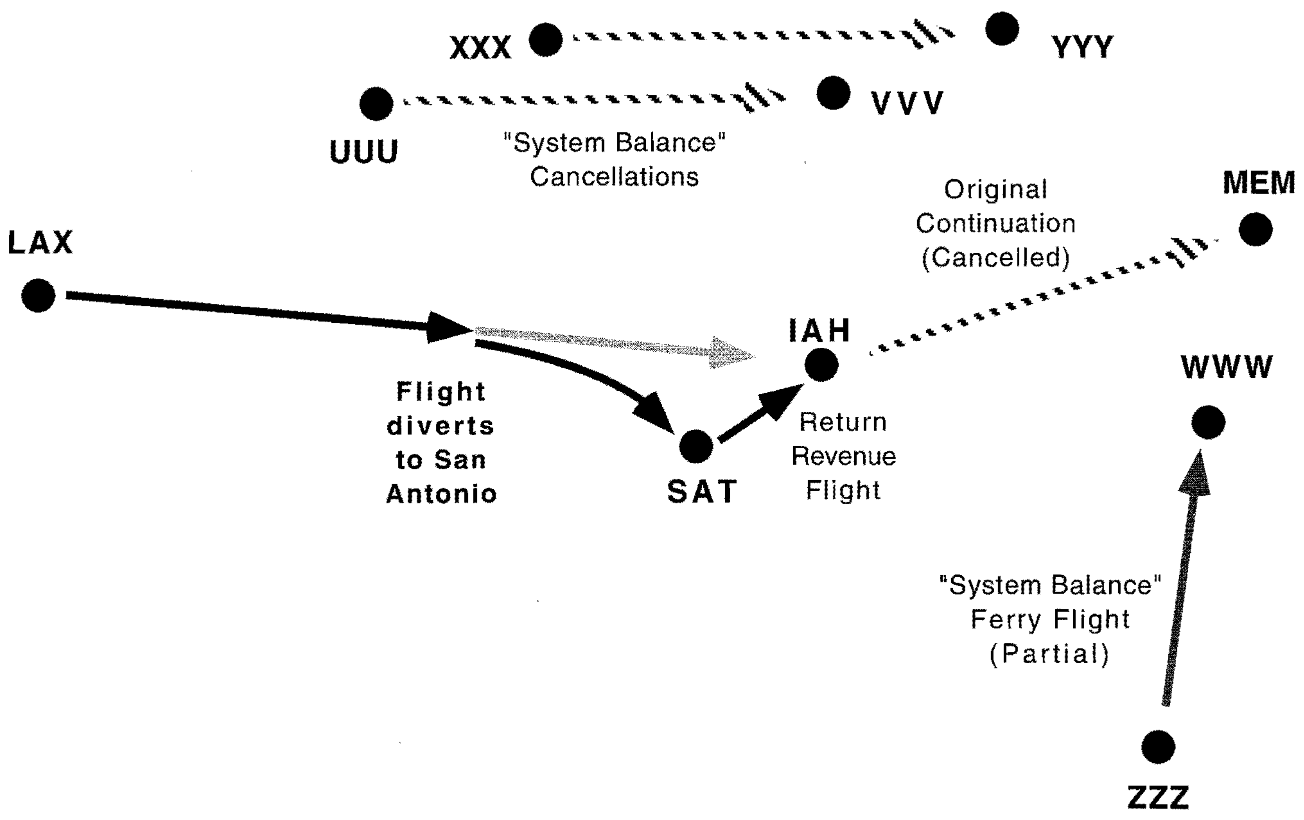
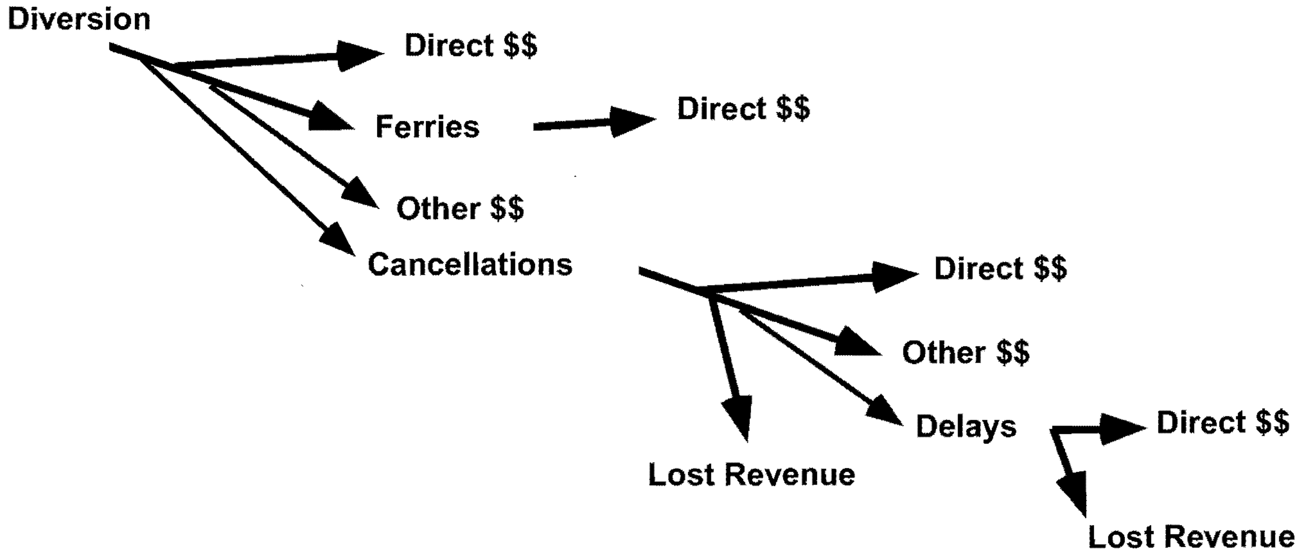


Figure 7. The Diversion Cost Tree



Recent studies at several airlines have indicated that average diversion costs can be as high as $150,000 and average cancellation costs as much as $40,000 (Irrgang and McKinney, 1992). The effects of diversions and cancellations on the airline are shown in Figure 7.

Smaller airlines have fewer direct costs than larger airlines, but also have a greater difficulty in recovery, which probably balances out. Some of the cost items in the irregular operation are as follows:

- Unplanned ferry flights.
- Extra flying and operation hours.
- Delayed passengers not directly on the weather-affected flights will produce a revenue loss, due to ill will. One can assume that passengers who are caught in the bad weather will have no ill will, as they can see it is a safety issue.
- Lost passenger revenue during the irregular operation, from canceled and overfilled (combined) flights.
- Hub operating expenses (staff and ground equipment shortages, producing extra activity and costs).
- Costs related to processing misrouted passengers.
- Mishandled bags.
- Extra passenger meals and hotel costs.
- Misconnected passengers.
- Increased passenger oversales and denied boarding costs.
- FIM (Flight Interrupt Manifests) costs — transferring revenue to other airlines for this airline's problems.
- System-wide cargo costs. If airplanes are more full when flying fewer flights, there will be a cargo cost.
- Tighter scheduling of crew, often resulting in crew shortages at the end of the next crew scheduling cycle.
- Ground cost items at other stations (staff overtime, unplanned refueling, catering, etc.).

The above items represent possibly half of the total cost of a diversion, and less than that of a cancellation. The remaining financial impact is a function of lost future revenue, due to the passenger ill will generated by a bad weather day. This ill will is highly variable, and will be of least magnitude for a carrier that caters to extremely low-fare and/or leisure travelers, but it will be worst for airlines catering to the business traveler. The model is shown in Figure 8, with representative impact figure (Barlow, 1991).

Operations Philosophy and the Irregular Operation

The airline operations environment is extremely dynamic. In all aspects of airline operations, resource schedules that optimize each given resource are built in advance of an operation. There are problems in carrying out these schedules:

- Interdependent resources are often scheduled independently. They are always managed independently (e.g., aircraft and crews, pilots and flight attendants, maintenance).
- The schedule can never be executed as planned, as minor problems from maintenance or weather will always exist, even in the absence of major irregular operations.
- Tightly constrained resources exacerbate recovery.

The recovery is left to experts with large amounts of experience in each particular area. Ultimately, improving an airline's irregular operations handling requires three elements in conjunction:

- Effective planning to reduce the impact of irregular operations in advance. The best approach here is to recognize key philosophical points, then modify system slack resources to obtain balance.
- Changing the way the airline operates during an irregular operation. This will reduce the *severity* of the diversions' impact.
- Implementing effective irregular operations decision support computer systems. This will cut the *recovery time* from the disruption caused by the diversions.

These are best if they are used together. In order to do this, significant re-engineering of the airline operations and computing environment may be necessary at many airlines. The weather cannot be prevented, and it is what causes the irregular operation. But implementing the above will reduce costs significantly.

To address the first point, we need to change the way an airline allocates physical resources. Consider Figure 9.

The best way to strengthen the flexibility of the airline operation at minimum cost is to balance the airline resources. Unfortunately, the tendency at most airlines is to reduce those resources viewed as spare (crews, spare aircraft, spare gates), while expensive resources that are unseen become inflated just to keep the airline running (especially doing overnight maintenance checks before they are due, which produces excessive and costly maintenance capacity).

When the airline is resource-balanced, in planning for the future, it should consider what defines and distinguishes operations from planning:

- Operations uses results of long-range scheduling/planning, does short-range scheduling (re-planning) and real-time re-scheduling (irregularity).
- Planning requires perfection, optimizations, exactness, based on constrained resources, defining software constraints, and interrelating different types of resources.

We often assume re-scheduling or repair has the same requirements as operations and planning. However,

- People try to improve a situation — not always finding the best answer. It takes too long to find best answers. So, we cope!
- Ideally, we want dynamic re-scheduling capabili-

Figure 8. The Passenger Ill-Will Model

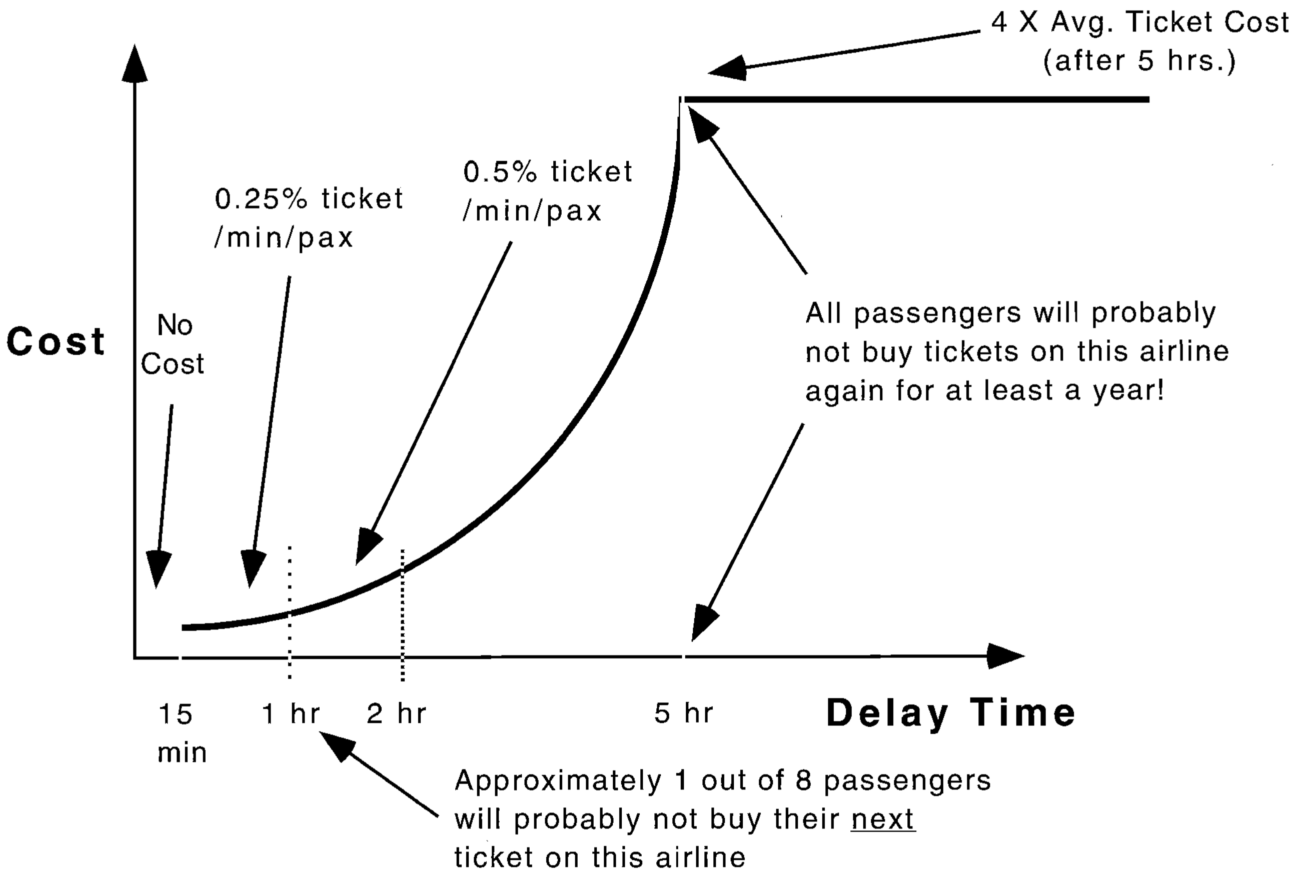
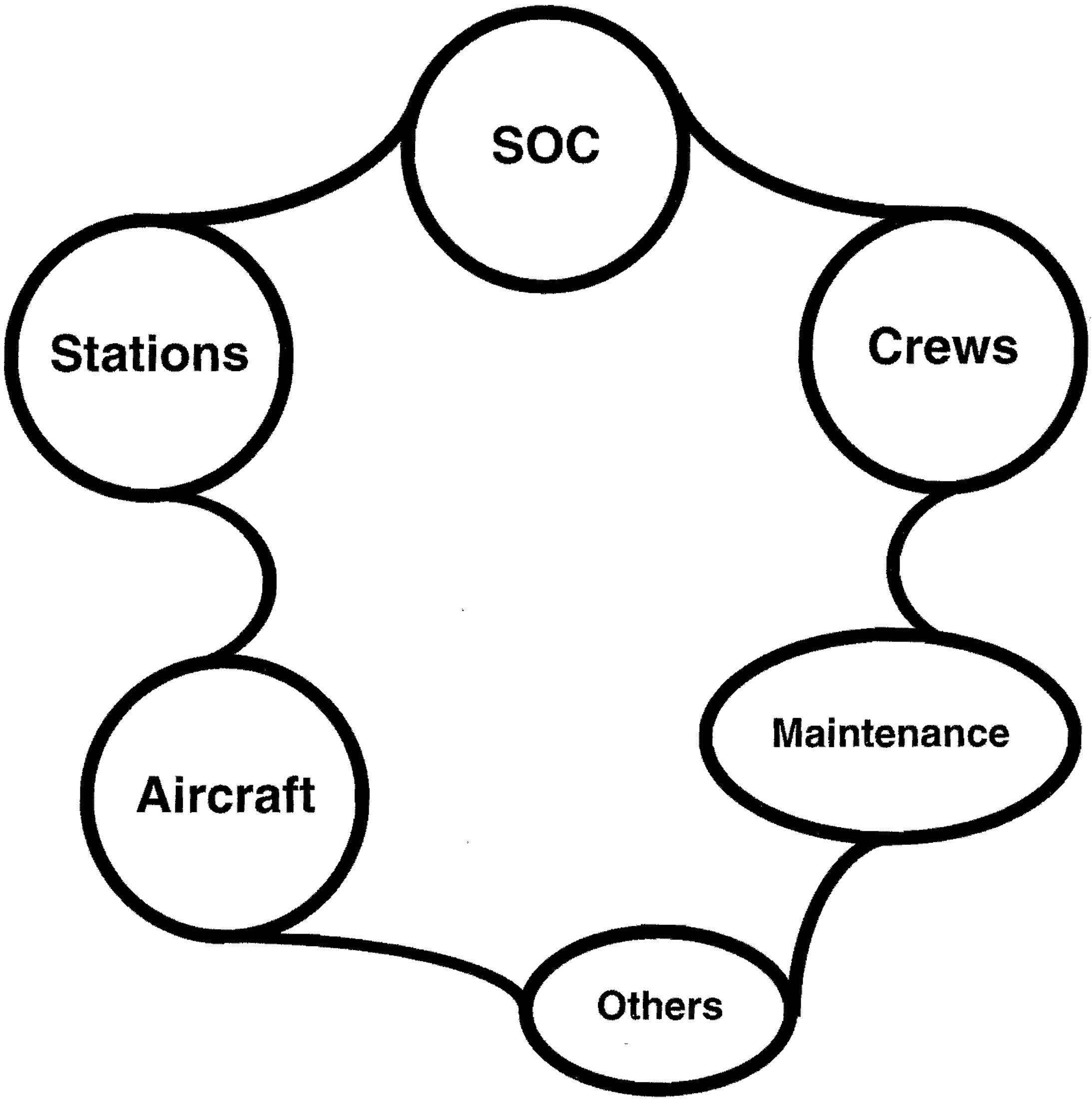


Figure 9. The Balloon Model



ties that take all factors into account. But this is too complicated because of resource constraints imposed by unknown combinations of random events.

- A successful solution is different from a best solution:
  - Timely results are much more critical,
  - Highest profit is not the main factor.
- The reduction of downline effects and implications is usually the main concern, to minimize further disruptions. This sometimes gives way to time.

The absence of an operating philosophy produces a need to resolve conflicting operating philosophies that exacerbate problems between different operations organizations, especially during periods of irregular operations.

To further explain the issue here, consider the number of different entities involved in any major operations decision:

- System Operations Control (SOC) is in charge of irregular operations decisions, and ultimately determines which flights are to be canceled or rerouted.
- Crew Tracking and Scheduling repairs illegal or missing crew problems.
- The major or hub airport involved in a weather disruption will have primary responsibility in any repair of its operation.
- Outlying airports where aircraft are diverted, or where flights may be canceled, will be involved in the repair process, etc.

Each of these groups will have information regarding a problem, which might not be completely shared with all other relevant groups. In addition, there may be a working plan toward a solution for a considerable period of time before the solution is reflected in the information systems. An example would be if a key flight could not be operated because there is no aircraft or crew, due to a diversion. It may be understood by everyone that this flight *will* operate; yet it might be an hour before the Flight Following and Information System (FFIS) reflects that fact, while various other flights are being restructured in order to provide aircraft. During the intervening time, what is the truth? The FFIS says the flight will not operate. *People* in SOC know that it will, because they *own* the relevant data and the decision. Therefore, relative to all decisions, the following questions should be asked:

- Who owns each category of operating data?
- Who controls decisions regarding that data?
- What should be done by each of the operating groups any time such data is questionable?
- How should other groups be informed that the data is questionable? For example, when is a cancellation *not* a cancellation, or a delay *not* a delay?

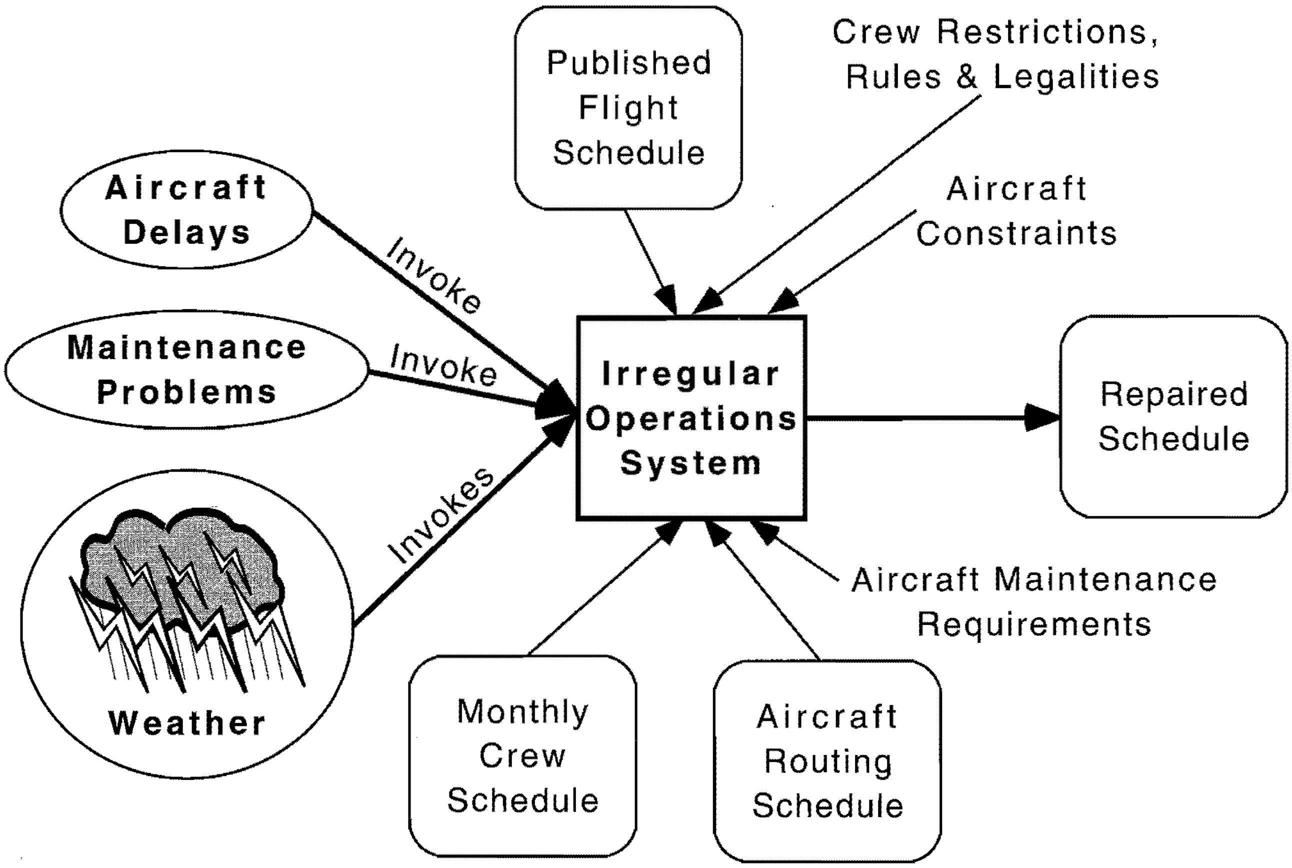
Resolution of these issues today is not a problem, because all issues and data are controlled by people, who adjust to changing circumstances easily. When decisions are all made with Decision Support Systems, and when the type of *information* and not just *data* within these systems is more complete and timely, then there *must be an operating philosophy* to allow for proper arbitration and to deal with incorrect or anomalous data.

An important concept to consider in defining an operating philosophy is that it is not sufficient to say, "we will fly the schedule and operate all flights on time," as this is too general and does not answer the questions of, "How do we make this happen?," and, "Who does what?"

An operating philosophy would consist of the answers to the above list of questions, combined with the following:

- A particular organizational structure.
- A set of priorities for recovery (e.g., what is the priority of passengers? Of cargo?).
- A set of operating procedures that covers as many cases as possible (e.g., under what circumstances should cancellation be a primary recovery tool? Under what circumstances is delay the primary recovery tool?).

Figure 10. The Irregular Operations Recovery System



- Last, but most important, who is in ultimate control in an irregular operation? The only acceptable answer to this is System Operations Control (SOC).

Considering the question leads an airline to ask, "if we don't have an operating philosophy, then how do we operate?" The answer to this is quite straightforward, historically. Different organizations have always had responsibility for the generation and modification of certain real-time data. As nobody else would be able to access sufficient data to influence a decision process in a given area until it was too late, he who had the data and controlled it also controlled the decision processes related to it.

With the advent of more sophisticated decision support systems, more and more data becomes available in real time, blurring the boundaries of control. For purposes of this discussion, it is constructive to define data in terms of global versus local:

- Global data is any data that will probably influence the entire airline, and which may be needed for making decisions outside a local confine, e.g., many things to do with gate shortages at IAH have such impact. This data must, therefore, be globally available and centralized.
- Local data is any data that is not needed to make other than local decisions and does not have global impact, e.g., the personnel work schedule within a given hub.

So, if this defines the data issues, then the key philosophy questions become:

- What are the appropriate local decisions?
- What are the appropriate global decisions, and who makes them?

As indicated above, most airlines seem to agree that SOC must arbitrate all global decisions, by definition, as it is the function of SOC to oversee and coordinate the global operation. Different groups may have specialized knowledge that needs to be fed into these global decisions on a cooperative basis, but SOC must make the final decisions, and communicate them to the other groups.

An airline operating philosophy would include, among other things:

- A definition of an arbitration process between different operations groups, especially during irregular operations, but also during problems in the normal daily operation.
- Assignment of the responsibility to monitor and decide when arbitration is necessary.
- A formalization of the relative values between tradeoffs that can be made during the operation process? (e.g., What is the relative cost of a controllable delay in dollars? What is the cost of a cancellation per passenger?).
- A formalization of the relative values between tradeoffs that can be made during the process of scheduling resources in advance (e.g. a correlation between the factors in the previous point and in how many resources are actually used to schedule. How many cancellations per month do we accept before we need to add an airplane, a crew, a gate, cut a flight).
- Guidance in solving irregular operations, etc.

Definition of an operating philosophy is a long and careful process.

Irregular Operations Management: Decision Support Computer Systems

Studies on irregular operations have shown that the single factor that can most significantly reduce the impact on the airline operation is the reductional recovery time. One way to do this is to build decision support systems to aid in the recovery process.

The most important element of this decision support is to show all of the downline effects of any event, and also to show all the downline effects of any proposed recovery from the event. An accurate view of the irregular operation can reduce its impact (Abrahamson, Lacher, and Fraser, 1994).

Such systems could be designed for any airline. Figure 10 illustrates the basic approach:

The system would provide graphical and textual viewing of irregular operation downline effects, as well as a "what if" scenario management capability to assist an expert in repair of the operation. The system would also allow comparison by various cost effect indices between solutions and problems.

Downline effects have meaning when measured as a series of costs. Costs are any elements that have a negative impact on the airline. Not all of them can be measured or projected accurately, and it is highly inappropriate to arrive at a single measure of cost, as the factors involved are as different as apples and oranges. *The relative value of apples and oranges changes with the situation. The user must be presented with the different factors, in order to make the judgment of their relative worth in real time.* The different factors that comprise the set of costs include the following:

- *Balance*: All resources are in sequences that end or pass through end points or vertices. Fleet balance, for instance, can be considered in terms of the end of the day (the usual SOC view) or in terms of the next required maintenance check, and being at an appropriate station (the maintenance view).
- *Delay*: Obviously, the issue here is flights, and delay can be accumulated in terms of minimum delay impact, i.e. if all resources deriving from a given flight problem prevent ensuing flights from

occurring on time, then if a computation of minimum time between flights is made, accumulate delay time assuming this minimum is achievable.

- *Misconnects*: Misconnected passengers, or diverted and canceled passengers are a key component of the indirect cost of any irregular operation, as it is difficult to track whether they reached their final destination
- *Direct costs*: Certain direct costs can be projected. These would include the cost of extra flying, using statistically computed costs per block hour, either of diverted flights or extra sections, if extra sections can repair. A converse of this is that a whistle stop or a canceled flight reduces direct costs.
- *Crew Problems*: Crew misconnects and illegalities render flights unflyable.

Once all downline effects are analyzable, the system can support comparison of different "what if" scenarios, and automatic generation of "what if" sequences with repairs introduced.

Changing the Flight Operation to Reduce Effects of Bad Weather

The preceding has focused on how to recover from disruption. Is it possible instead to reduce or eliminate the disruption prior to its occurrence? In many cases, this is indeed possible. The remainder of this chapter explores a new methodology for operational changes to reduce disruption before it occurs.

Changing the Way the Airline Operates

A new approach to planning flights during bad weather, called the Dump Plan, has been developed that significantly reduces the degree to which the airline gets out of sequence. It was presented to the FAA and was well received. Portions of the plan have been adopted by one airline. The plan can be adapted to the operations of any airline for its major hub(s).

In addition to hub-and-spoke operations, the plan also can be used to operate normal point-to-point flights, or turn (out-and-back) flights. The magnitude of the savings will not be as high, but the same principles will hold.

Dump En Route Instead of Divert

This alternative for planning flights during irregular operations is to operate into an affected hub with an approach that is similar to the concept used in international flight operations of re-clearance upon passing near an en route alternate; i.e., the approach is to plan diversions in advance. This involves a major philosophy shift from the current method, which is to always hold in bad weather until one can either land or one has to divert. In the new approach, holding in bad weather is considered to be unacceptable; if one is unlikely to be able to fly to the destination after vectoring or a short hold, then one lands short at a preplanned, en route alternate, i.e., one reclears with the airline's System Operations Control upon passing close to the en route alternate.

This method substitutes additional minor delays for a reduction in disruption. In the process, it saves significant fuel and other operating costs, and reduces passenger disruption.

The plan is called a dump plan, or a landing short plan, as it involves dumping flights out of the air early and landing them short of their destination. Details of the plan are given below.

This approach has the most beneficial effect when dealing with a banked hub operation; however, it can even provide some incremental reduction in costs for individual flights.

The approach would be used any time there is a forecast of severe weather at the hub. All flights expecting to arrive during the possible period of bad weather would have their flights planned differently than normal.

The Details of the Current Approach

First of all, what is a normal flight plan, and how does this relate to the operation of the normal flight? A flight plan for a U.S. domestic flight when there is a forecast of poor destination weather would typically include the following fuel components:

- Fuel to taxi out, take-off, climb, cruise to the destination area, and have a normal landing.
- Fuel to hold for traffic or bad weather.
- Fuel to attempt and miss an approach, then climb to a low altitude, and cruise in any direction to a planned alternate airport.

Now, the way this plan would be executed, and the way that the fuel would be used would be more likely to include these elements:

- As planned, taxi out, take-off, climb, cruise to the destination area.
- Probably (on a long-range flight) save some fuel by requesting more direct routings than filed with air traffic control. Also, possibly gain fuel from slightly more efficient altitudes en route.
- Perhaps waste some fuel flying some inefficient altitudes.
- Fuel and time are wasted to vector if there are traffic or minor weather problems.
- Fuel and time are expended to hold for bad weather, if necessary. When holding for bad weather, ATC usually only communicates with pilots in 30-minute intervals, telling them "EFC 30" (expect further clearance, or information, in 30 minutes). This means that any decisions regarding

diversion must be made when at the threshold point of fuel to fly to an alternate, land, and have reserve. This will be, at the latest, with about 80 minutes remaining fuel. An EFC 30 is therefore not reachable with less than 110 minutes of fuel, including reserve.

- During holding, the aircraft is perhaps 50 miles from the destination. If it is necessary to divert, diversion is done from the holding point to some airport nearby, and on the same side of the weather as the holding point. This may or may not be the originally planned alternate airport.
- The fuel that was planned for the missed approach is used for some of the extra holding. In addition, some of the alternate fuel may be used for holding, as the hold point is possibly closer to the alternate than the destination.

In other words, the plan bears little relationship to the actual flight in bad weather. Also, the actual flight involves landing an aircraft in the wrong place, very late, and very low on fuel.

The Details of the Dump Approach

Instead of taking delays in the air by doing extra flying, when using the dump approach, flights actually land a half hour or more before their scheduled arrival at an alternate airport en route to their destination.

The dump plan is implemented for a major hub any day there is a forecast of severe weather. The sequence of events is as follows:

- Pre-plan en route operational alternates for all flights beyond the first tier of destination cities. These are the potential dump flights.
- An operational alternate is an alternate that you are intending to use, as opposed to the alternate that would be filed on the flight plan (refer to the missed approach discussion above).
- The first tier are those cities within about 45 minutes flying time of the hub. They are usually in the same air traffic control region as the hub. Flights from those cities would be held on the ground in the event of bad weather.
- Prepare multiple flight plans and plan fuel accordingly for all potential dump flights, i.e., plan the intended flight, plan a flight to the operational alternate, and plan a flight from the alternate to the destination, all in advance. Design the extra two plans so as to require only minimal or no refueling in the operational alternate. This can be done for most aircraft types on most of the possible flights. It involves carrying some extra fuel, and being concerned about the landing weight at the alternate.
- The dump plan would be triggered and all inbound airborne flights would be landed, without holding, at their operational alternates if the destination were likely to be closed upon their arrival. The trigger point for each flight would be as it approached within 50 miles of its operational alternate.
- By the time a flight is within 45 to 60 minutes of arrival, a reasonably reliable prediction can be made as to destination weather.
- In the United States, the FAA, in fact, has a procedure that would provide an accurate prediction as to destination disruption. Called a first-tier ground stop, it is when the FAA is holding flights on the ground with the assumption that they cannot make it to destination. However, it must be a ground stop only for conditions unacceptable for landing, not just for reduced traffic flow.
- Land immediately at the operational alternate. Do not hold. Holding for bad weather would be prohibited for flights to a hub.
- If the flights have already come in past the first tier when the severe weather begins, immediately divert to the operational alternate without holding.
- At the alternate, add only minimal fuel (0 - 5,000 lbs. for most aircraft types on most potential dump flights) needed to resume the flight. Take off as soon as clearance is received from ATC, after the hub has opened up again.
- Resume flight into hub.

Dump Results and Implications

The benefits of the dump plan are as follows:

- The airline can no longer get out of sequence from an irregular operation (by definition). All crews will make their connections (where legal). All passengers will make their connections (by definition).
- There would be reduced crew illegalities, another frequent side effect and exacerbator of irregular operations. Today we have a window of illegality. Afternoon diversions can cause crews to become illegal while they are waiting in the alternates, further complicating recovery. This window would be reduced. Most illegal crews would now be in the hub—usually a crew base for most airlines— thereby easing recovery.
- Cancellations now would only be necessary where desired. None would be necessary to bring the system back into balance for tomorrow's flights.
- There would be a considerable reduction in actual flying time per diverted flight, about 2 - 3 hours worth.
- There would be greater capacity in the alternates for aircraft.
    - Fueling time for diverted flights would be cut by at least a factor of 10, because the flights would not hold.
    - There would be no need for gates at the alternates, except for minimal time for fueling, be-

cause it is not necessary to deplane passengers at the alternates. Today, as there is usually no advance knowledge of what will be done with the passengers, they are often deplaned.

The costs of the dump plan are as follows:

- Occasionally, flights would be dumped unnecessarily, from sudden changes in the weather.
- More flights would have delays in bad weather. However, all of these delays would be much shorter.
- It would occasionally be necessary for flights to sit for lengthy periods of time on the ground at the hub, because of potential timing problems and gate shortages, in order to preserve flight sequencing. This would only be a problem for U.S. carriers, however. Most overseas airports already use far more hard stands than gates with jetbridges.

Some philosophical conclusions:

- We are trading unknown disruption for certain delays.
- It is better to have more flights dump than the diversions we have today, because of the cost savings and reduced disruption.
- It is better to have delays if they provide the certainty of making connections. The airline now would provide the passenger with improved dependability of operation and results.
- In effect, the priority of passengers is now boosted in resolving irregular operations.
- Today, it is the uncertainty that inconveniences the passenger most.

Questions on Dumping

People who are extremely familiar with airline operations will have a number of doubts and concerns about dumping, due to the radical nature of this plan. A key issue—has enough been considered in the development of the plan? This section raises and answers a number of likely questions:

- Will this work for all flights?
  - No, probably not. But rather than disrupting 2/3 of an arrival bank, about 10% of a bank would probably be disrupted.
- What if a bank still lands ahead of the previous one?
  - Use any spare gates. Then wait to process the preceding bank in order of arrival.
- What does this do to bank timing?
  - A typical situation would be a 30 - 60 minute airport disruption. This should result in about a 1 and 1/2- to 2-hour delay. All operations through the hub will now be delayed for the rest of the day. It may be possible to make up a few minutes per bank, however.
- What if the airport weather disruption is longer than 60 minutes?
  - The next bank could also land en route, if necessary. Eventually, aircraft could be held on the ground at their origins.
- What is actual timing of dumping (over and above original flight plan)?
  - 10 - 20 minutes to deviate from flight path to land at alternate.
  - 5 minutes taxi in.
  - 20 minutes to refuel minimally.
  - 5 minutes taxi out.
  - No additional time before the hub is accepting traffic again, in a typical thunderstorm scenario. Longer in snow. Somewhere between the two for fog. (Note that 40 - 60 minutes have now been used).
  - 5 - 60 minutes for new ATC clearance.
  - 5 minutes additional flying for new ascent.
  - 0 - 20 minutes to possibly fly around weather.
  - 50 - 135 minutes total time. As not all flights have the maximum of this range, this makes the maximum likely hub delay under a typical weather session (thunderstorms) about two hours.
- What is the impact of ATC (U.S. FAA)?
  - ATC will not immediately clear flights to relaunch. On the good side of the weather front, there should be a 30-minute clearance time. On the bad side of the weather, clearance should require up to 60 minutes. Also, flights on the bad side may need 20 minutes of extra flying.
- What is the fueling of flights under this approach? How does it compare to what is usually done today?
  - Flights would be planned for a fuel minimum of a normal alternate plus hold time based on actual historical delays. Today, when diversions might be possible, many airlines will often fuel flights full. If pilots were concerned about this lower fuel level, maximum landing weight at alternate could be the determining fuel limit.
- Won't this cause flights to exceed their maximum landing weight at their en route alternate?
  - Computing flight plans with typical or heavy loads does not appear to cause any severe load restrictions. For instance, an MD-80 landing short would have about 2,000 pounds to go to maximum landing weight when planned for a 32,000-pound payload.
- What if this plan breaks down in any given irregular operation?
  - It will merely degrade into today's common practice. For instance, the worst case would be when part of a first bank arrived, the rest dumped, the third came in, but then the weather deteriorated such that the rest of the first could not get in, all over a several-hour period. At that point, we would just have to

deal with those aircraft we had in the hub.

- What if there are successive waves of weather, hitting multiple banks?
    - The plan should still work, if it is applied continuously in sequence.
- What if the weather at the en route alternate is bad? Is there a safety problem? Where should the airline be diverting flights to?
    - There is no safety problem, as in effect, there is 30 minutes of additional hold fuel for that destination. It would be a good idea to plan two operational en route alternates for all flights.
- What about holding flights on the ramp or taxiway at the hub? What if most of the passengers had the hub as the final destination?
    - *These* would be the flights that could get any spare gates. This decision can be made dynamically.
- What if ATC refuses to cooperate?
    - This plan has been discussed with the FAA. It is true that current procedure would cause them not to launch recovery of dumped flights quickly. However, we have pointed out that, while approach control workload goes up, overall ATC workload is reduced, because planes spend much less time in the air (elimination of holding). This *enhances safety!*
- Is there a communications impact and a dispatcher workload impact in an airline's SOC environment?
    - Yes. All long-range flights on possible dump day have to be planned three different ways—to destination, to alternate, from alternate. Dispatchers need to transmit dump orders to pilots. Automation assistance could reduce this.
- What is the downline ruboff effect to an airline's other hubs?
    - In effect, research shows that up to half of a large airline could become delayed, as the day progresses. It should be noted, however, that this often occurs today. The length of the average delays which will occur under the dump plan may be significantly greater than some of those today, but the number of flights delayed may not be greatly increased. Delays will be normalized the extreme delays experienced today will be reduced. Cancellations all over the airline would be considerably reduced.
- Would the dump plan overload the close-in cities used for en route landings?
    - It is likely that landings per alternate would increase under this plan. However, the processing impact per flight in the alternate would be much lower, because of less planned ground time negating the need for passenger servicing, and higher fuel-on-board reducing the amount of fueling and gating.
- Would the additional delays overwhelm an airline's capacity to provide crews?
    - If the dump plan were implemented early in the day, there would be higher impact on crews than there is today. However, when an airline has illegal crews today, they are often in the alternates and or first-tier cities, creating additional problems. Also, as delay is propagated through the day—crews could be notified to start duty time later several banks out. The various factors should cancel each other out.
- Is dumping a binary decision? Would all flights always dump?
    - No. Long-range international flights might not even dump at all. Also, the timing could be such that some flights have already landed prior to the dump decision being taken. In this case, anticipated timing would govern how the situation could be handled.
- What triggers an FAA ground stop in the United States? Is it possible to predict?
    - The ATC mechanism for ground stopping is as follows:
        - There is an increase in miles in trail.
        - There is a reduction in rate of traffic flow into the hub.
        - One or more pilots will refuse to takeoff or land.
        - The local center will institute an internal ground stop (affecting some cities, about 100 - 150 miles out).
        - The first tier of ATC centers institute a ground stop.
    - This process can take hours or minutes, and may or may not progress all the way. Maintaining tight communication with the local ATC center could enable an airline to better predict the likely outcome of any such process.
- Are there any overall safety implications of the dump plan?
    - Yes. When this plan has been discussed with pilots, they have very enthusiastically endorsed it. They would much rather be sitting safely on the ground than indeterminately holding in crowded skies in bad weather.
- What are the fundamental problems in implementing the dump plan?
    - A major problem is that nobody would want to take responsibility for triggering a dump. It would take a strong upper management commitment to the plan, without minimal risk of

career consequences for an imperfect decision. "Monday morning quarter-backing" affecting the individuals involved would have to focus not on whether the dump decision was the right one, but rather whether it was correct *given the information available at the time.* Whether or not the decision was correct in the *absolute* sense should only affect the details as to how we modify the dump program.

Summary

Weather-related irregular operations — the management of and recovery from disruptions — is extremely expensive for every airline, especially those with a hub-and-spoke approach to flight scheduling. Each of the following methods can apply in some degree to any airline with more than one aircraft, however. All of these methods work best when combined with each other.

An airline can take several approaches to controlling its irregular operations costs. These fall into three areas:

- Management method changes
- Decision support systems
- Flight operation changes

An ideal approach to reducing irregular operations impact would actually include developments in all three of these areas. The first two have tried and true approaches to them. These will merely be listed in the paragraphs below. It is less obvious how to change the flight operation — this is the point of the main body of this chapter.

Management Method Changes

The first area for an airline to examine in order to reduce the impact and severity of irregular operations is how the total operation is managed, the allocation of resources (Beatty, Murthy, Miller and Sorenson, 1995) and what effect that may have on both the degree of impact and the speed of recovery from an irregular operation. Some of the different areas that can provide significant results include:

- Extensive business process re-engineering of the operations aimed at increasing centralization of information and simplification of recovery.
- Planning resource allocations (crews, aircraft, gates) for the bad-weather operation, as well as the good-weather operation.
- Balancing slack resources in the airline (aircraft, crews, maintenance capacity, time-to-maintenance-check, gates) to have the same percentage excess capacity in all areas.
- Scheduling resources to enhance recoverability (scheduling flight and cabin crews together, scheduling crews and aircraft together as much as possible, scheduling strategically selected long turns, spare aircraft disposition based on past problem history).

Decision Support Systems

If recovery time from an irregular operation can be reduced, costs can be cut. Studies have shown that systems that provide a rapid view of problem details and severity not only enhance recovery, they reduce the severity of the initial irregular operation (Abrahamson, Lacher and Fraser, 1994). Some of the key features of a comprehensive irregular operation recovery system would include:

- Graphic display of weather, aircraft positioning and current problem flights.
- Graphic and textual information of all current flight status data, including diversions, cancellations, mechanical problems, delays, passenger misconnects, system resource imbalances, flight and resource schedule discontinuities.
- Analysis and display of downline effects of all current problem flights, as defined above.
- Simulation of downline effects.
- Simulation of repair scenarios and comparative cost analysis of multiple repair scenarios.

Flight Operation Changes

The disruption of an irregular operation could be largely eliminated in many instances by changing the way flights operate during bad weather. The principal change would be to reduce or eliminate holding when destination airports are closed. One should plan to interrupt flights en route, with fuel and time remaining on the original flight plan, instead of diverting after extended holding. This approach reduces direct costs in many ways, but also significantly reduces downline disruption, as the sequential nature of the complete integrated schedule is largely preserved.

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