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A Conversation With …
Enrique Beltranena, Volaris
Chief Executive Officer
and Managing Director
Page 10.

6 Afriqiyah Airways knows when and where to expand

32 Significant improvements to air traffic control systems

80 Effectively diagnosing MRO issues and prescribing solutions

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In Unison

Airlines can realize sizeable benefits by syncing up their scheduling processes and leveraging integrated decision-support systems.

By Sergey Shebalov | *Ascend* Contributor

Airline planning is traditionally performed in several stages. This separation happened due to high complexity of the involved challenges as well as airlines' business structure where different units are responsible for completion of various tasks. Following this practice, most decision-support systems provide solutions for a specific task. However, scheduling processes affect each other, and significant benefits can be achieved if decisions are made simultaneously.

Decision-support systems have been widely used in the airline industry for nearly 50 years. Currently, many of them work as integral parts of the planning and operations control processes. Airline scheduling represents one area that has probably benefited the most from employing these systems. These benefits are due to the ability of decision-support systems to automatically consider multiple constraints and objectives and obtain optimal solutions within operationally accepted time limits. However, the full potential of decision-support systems utilization is far from being realized. The airline scheduling process usually begins at least a year in advance and continues all the way to the day of operations. The goal is to optimally allocate all available resources — aircraft, crew, airport slots, ground equipment, maintenance facilities — according to the airline business model. Until recently, complexity of airline operations never allowed creating a complete and computationally tractable model describing creation of a schedule. To overcome this difficulty, the scheduling process is divided into several stages such as network development, fleet assignment, crew scheduling, revenue management and maintenance planning. Following this approach, decisions are made sequentially, so an output of one stage is used as an input for the next one. Consequently, most of the currently used decision-support systems are specialized in solving one or several closely related problems occurring within a particular scheduling stage.

A major disadvantage of this approach is sub optimality of the overall solution. By fixing some of the decisions on the earlier scheduling stages, flexibility of the later ones is reduced and, therefore, they may yield poor results. On the other hand, ignoring some of the restrictions early often cause infeasibility later, and the process has to go through several manual feedback loops before an acceptable solution is obtained.

Recent developments in operations research algorithms and improvements in quality of accessible hardware resources provided an opportunity to combine some of the scheduling problems and attain solutions unreachable via consecutive method. In addition, integration leads to standardization of information streams, simplification of communication processes and better administration of business practices.

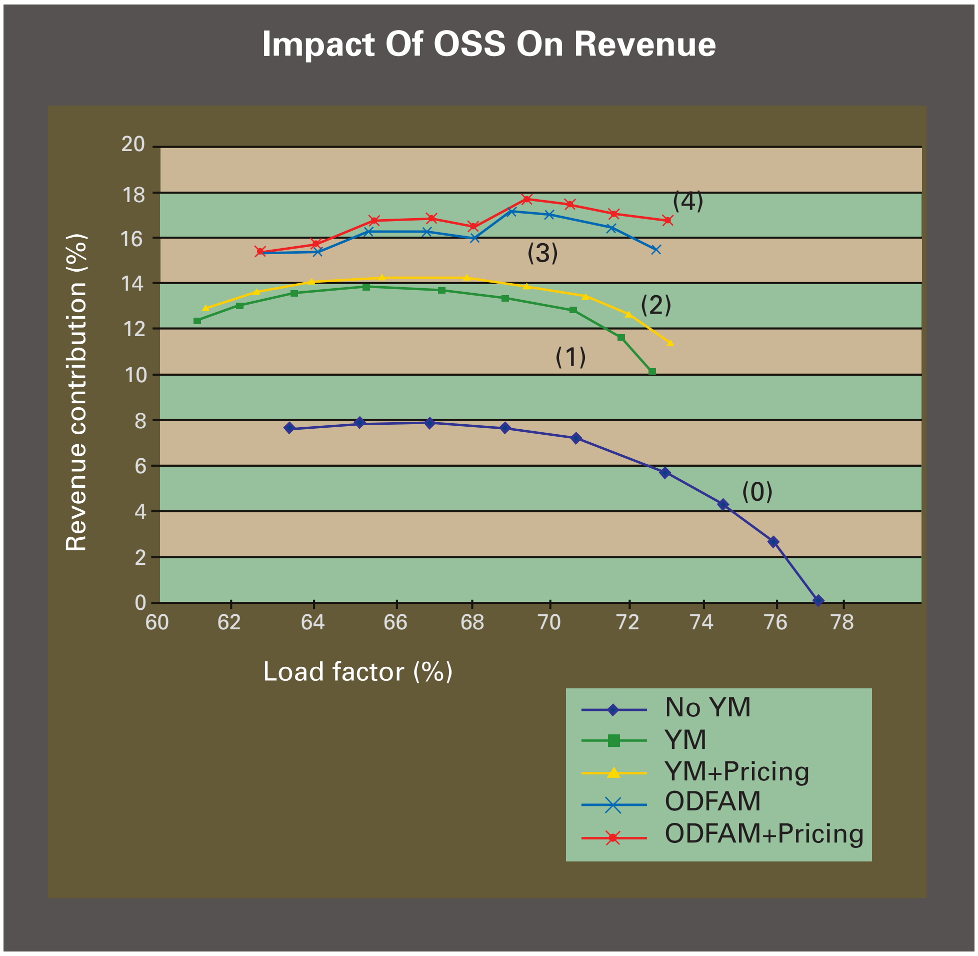
Integration is a complex concept that can be realized on several levels, such as integration of automated decision-support systems. To take advantage of all benefits provided by these systems, integration on other levels — such as data storage and manipulations, business objectives and performance measurements, organizational structures, and processes — must be implemented.

Integration Opportunities

Airlines can benefit from integrated decision making as it pertains to scheduling processes. Four examples — demand-driven dispatch, network development, integrated routing and integrated recovery — are not meant to provide a complete picture of the airline scheduling process, but rather illustrate several key areas where clear opportunities for integration exist.

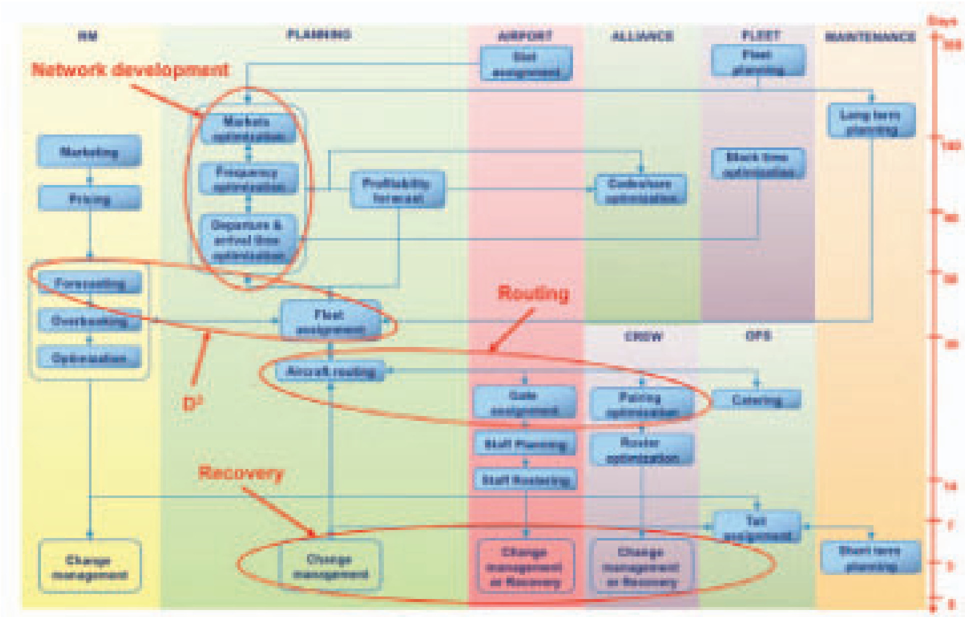
Demand-Driven Dispatch

A classic example of integration in decision making is close-in re-fleeting or demand-driven dispatch. This process combines fleet assignment and revenue management practices. During the fleet assignment phase, each flight is assigned a specific aircraft type so the schedule is operational and produces maximum profit. This process is usually completed two to four months before operations and is done on an aggregated level for a typical day or week. Revenue estimation is based on strategic passenger demand forecasts that account for influence of competition and network effect but does not use fine adjustments practiced in revenue management. Consequently, close to the date of



Simulation results demonstrate potential revenue improvement from application of integrated DSS to airline fleet assignment process. Each curve represents a potential revenue improvement as a function of load factor. The lowest curve (0) describes the solution obtained by a stand-alone leg-based fleet assignment model. Other curves show the effect of consecutive integration of revenue management, network connectivity and pricing considerations into this model. As a result, revenue grows by 8 percent to 12 percent.

Airline Scheduling Process



Airline planning is a complicated, multistage process with numerous interdependencies and feedback loops. Different stages of this process employ specific decision-support systems that are often inconsistent in objectives and constraint. Multiple opportunities exist for integration of these systems that would lead to significant improvements in airline profitability and operational robustness.

departure, it might become obvious that the aircraft type originally assigned to a particular flight is not optimal. In this case, the flight is either under capacitated and some of the valuable demand is spilled or over capacitated and some of the seats on an aircraft are spoiled.

On the other hand, revenue management operates on a much more detailed level. Compared to a strategic forecast that includes only average total number of passengers expected to travel on a flight across the entire period of operations, a forecast produced by revenue management systems has information for each flight on a particular departure date for each booking period, fare class and point of sale. In addition, 10 to 20 days before departure, a significant portion of bookings for the flight is already observed and, therefore, information about expected load is much more accurate.

Using this information, some fleeting decisions can be changed so assigned capacity better matches expected demand. These decisions have to be made carefully since most scheduling stages following the original fleet assignment are already completed at this point, and there is no time to adjust their results for the new assignment. For this reason, adjustments made to a schedule are usually limited. For example, if two aircraft belong to the same crew family, their swap would not disturb crew assignment. Aircraft rotations can also be preserved if only out-and-back cycles in a hub-oriented network are swapped.

This idea was first introduced in 1993. Since then, several different implementations have been realized and successfully practiced. Reported results vary depending on sophistication level of involved scheduling and revenue management practices. The most advanced systems provide up to 3 percent revenue increase.

Network Development

Network development is completed far in advance and includes several important decisions.

First, network structure is identified by selecting new markets that should be served by an airline and current markets where service should be discontinued. This decision should be consistent with an airline's business model that specifies either point-to-point or hub-and-spoke network type. In addition, market performance evaluation is affected by multiple macro-economic and service-related factors. Market selection is tightly connected to codeshare agreement optimization. An airline can serve a market either by using its own equipment or by marketing flights operated by a partner airline. Optimal choice of partner flights to be marketed by an airline as its own and revenue proration schema can significantly improve airline network potential.

Second, service frequencies should be determined for each local market. It is well known that dependency between frequency and demand shares is described by an S-shape curve. This means that an airline with higher frequency share obtains unproportionally high demand share. Thus, serving a particular market might be profitable only if frequency is high enough to make an airline competitive.

Finally, departure and arrival times of each flight should be chosen so total network connectivity is maximized. These decisions affect not only originating and terminating passengers by providing them service at the most convenient time but also passengers making connections. Instead of evaluating each market individually, a decision-support system should assess performance of the entire network as a whole. Often times local demand is not significant enough to make a market profitable and only contribution from high-yield connecting traffic justifies operations. In addition, block times for each flight can also be optimized by taking into account revenue potential, reliability and cost of the schedule.

Clearly, all these decisions affect each other and to achieve maximum results, they should be made simultaneously. There are two main objectives that should be kept in mind while the network is constructed. First, total revenue potential should be maximized. Generally, revenue calculations are based on a forecasting system that is able to estimate traffic for each available itinerary. Most forecasting systems utilize customer choice models and follow a well-structured process:

- Total market demand is estimated for each market an airline plans to serve.
- All possible itineraries available to a customer are constructed.
- Each itinerary is evaluated according to multiple quality criteria such as total travel time, number of connections and departure time.
- Total market demand is split among all itineraries according to their utilities and spill, and a recapture model is used to account for capacity restrictions and obtain traffic values.

Second, the resulting network should be operational with available resources. It is impossible to make sure the schedule satisfies detailed resource constraints at this stage of the planning process. However, incorporating major restrictions on an aggregate level ensures a smooth transition to future stages of the planning process. The network should be balanced, connected and consistent with operational characteristics of an airline's fleet. Required utilization of aircraft, crews, airport gates and other key recourses have to be within realistic limits. In addition, international service agreements as well as slots availability, airport curfews and other constraints must be satisfied.

Network development is one of the most difficult areas of the planning process to formalize, and truly integrated decision-support systems are still under development. However, preliminary studies show that overall revenue impact from optimization of an airline's network structure can be as high as 8 percent.

Integrated Routing

Once the network structure is determined and fleet assignment decisions are made, flights served by aircraft of the same type should be linked together. Aircraft routing is a process of sequencing flights into lines of flying that later can be assigned to a particular tail. Crew routing or crew pairing is a process of sequencing flights into pairings that later can be assigned to a particular pilot or cabin crewmember. Traditionally, these two processes are completed sequentially starting with aircraft routing that is later used as input for crew routing. The idea is to have an assignment with crew following an aircraft, so the number of times pilots or flight attendants have to switch aircraft is minimized. Many airlines use this approach to reduce the impact of schedule disruptions caused by weather or aircraft maintenance issues. However, fixing flight connections at the aircraft routing stage significantly reduces opportunities for crew cost minimization.

To overcome this limitation, aircraft and crew routings can be built simultaneously. During this process, flight connections that minimize crew costs, satisfy aircraft operational constraints and maximize revenue are prioritized in a series of iterations. Thus, the system is incentivized to use the maximum number of such connections in a solution, and crews are guaranteed to stay with the same aircraft as much as possible. This approach helps reduce crew costs by about 1 percent without sacrificing schedule robustness.

Aircraft routing decisions can also be integrated with gate assignment and maintenance scheduling processes. Gates at each airport are assigned to a pair of arriving and departing flights; therefore, aircraft routing is an input for this problem. However, gating decisions are usually subject to many restrictions such as time-related constraints, adjacent gates availability and custom requirements. In addition, gate planners usually have their own metrics, measuring quality of an assignment. Aircraft routing that is built without any knowledge about these constraints and objectives could result in a poor gate assignment or no feasible solution at all.

In this case, rotations are adjusted manually with several feedback loops between ground operations and schedule planners. Instead, all gating constraints can be enforced at an aircraft routing step; therefore, resulting lines of flying would produce a gating solution for each station as a byproduct. Similarly, if maintenance requirements are taken into account after aircraft rotations are constructed, then multiple schedule adjustments might be necessary to satisfy existing regulations. These modifications might cause aircraft and crew underutilization as well as maintenance work load imbalance. Therefore, simultaneous development of aircraft rotation and maintenance schedules can significantly reduce operational and maintenance costs.

Integrated Recovery

Although it is not optimal, the planning process still can be done in stages as schedulers have enough time to coordinate their solutions and reiterate the processes if necessary. The situation is drastically different on a day of operation when a disrupted schedule has to be recovered in a matter of minutes. Delays caused by aircraft mechanical failure, crew unavailability and especially weather conditions can easily affect all areas of airline operations and propagate through a large part of its network. Flights might need to be canceled, diverted or delayed; aircraft and crew rerouted; and passengers reaccommodated.

If these decisions are made independently, the quality of the resulting recovery solution might be low. For example, if a flight is delayed, the crew might not be able to operate it any more due to legal restrictions on the length of a duty. In this case, a reserve crew has to be used, resulting in significant extra expense. In addition, transferring passengers from the flight are likely to miss their connections, and they will expect some type of compensation such as tickets on another airline or meal and hotel vouchers.

Multiple recovery options often exist, and they have to be evaluated with respect to all involved factors in a short amount of time. If an airport's capacity is reduced, an airline receives limited number of slots and should choose the most critical flights to be operated with all others delayed or cancelled. The efficiency of a recovery plan is usually measured by the time required to bring operations back on plan and a combination of factors such as number of cancelled flights, delayed flights, deadheaded crews and unaccommodated passengers. An integrated approach recently tested in a disruption simulation environment showed a double-digit percentage improvement — including a 12 percent decrease in passenger delays and 69 percent improvement in crew deadheads — in multiple categories compared to a sequential recovery method.

Others

There are many other areas where integrated decision-support systems would provide significant benefits. Systems used in revenue management can incorporate decision making in pricing and marketing as well as account for auxiliary revenue opportunities. Airport scheduling systems should simultaneously consider gates, ground equipment, luggage systems and ground crew. Integrated crew scheduling needs to combine pairing and roster optimizations for both cockpit crew and cabin crew and, in addition to costs, take into consideration such factors as crew preferences and fatigue measures.

Challenges And Opportunities

Despite the fact that benefits of integrated solutions are obvious, there are several obstacles that prevent quick adaptation of those principals in practice. Probably the most prominent is the existing organizational structure of airlines' planning departments, where different business units are responsible for the completion of various tasks. Performance of these units is evaluated within their silos, and they don't include their effect on others. Consequently, these units tend to optimize their own metrics, and since these metrics often are not consistent with each other, the overall performance is far from optimal.

Another issue is consistency in data flows. For different systems to be capable of sharing information, their data interfaces should be standardized. Airlines typically use some internally built systems and others provided by various external vendors. These systems are developed in different periods of time and use different data manipulation technologies and data organization principles. Achieving consistency in this area is a costly and labor-intensive task, but it is absolutely necessary for the success of the integration effort.

Finally, computational complexities of integrated models require application of advanced mathematical algorithms, usage of powerful computers and, therefore, high qualification of decision-support system users and maintenance personal.

Decision-support systems currently focus on solving problems in specific areas of the planning process. Integration of these systems can significantly improve quality of resulting schedules and strategies. However, due to the significant length of the scheduling horizon and complexity of involved processes, it is impossible to collect all decision making into one model. Instead, individual decision-support systems can be linked together so a flexible scheduling environment is created. In this environment, individual systems should be connected to each other through shared objectives and consistent restrictions. Each system should be able to react automatically to internal schedule modifications and external factors.

Several key conditions have to be satisfied for the successful integration of decision-support systems:

- Standard data interfaces must be established between different systems.
- A clear depiction of how the processes flow should be established, and operational constraints and objectives should be made consistent across all integrated areas.
- Administrative resources involved in the integration effort should receive proper training, and their performance metrics must be based on overall system characteristics.

Despite considerable challenges, benefits of integrated decision-support systems clearly outweigh implementation costs. In a highly competitive airline industry, staying on the leading edge of technology is essential for successful operations, and decision-support systems integration is one of the most promising directions in this area.

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