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An e-Transformation Study Using the Technology–Organization–Environment Framework

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Abstract

Aviation information in the cockpit and on the ground was almost entirely paper based until a decade ago, when a digital future became apparent. This digital future requires industry transformation, which is influenced by the technological, organizational and environmental (TOE) context. This study uses an adapted e-business TOE framework to analyze drivers, facilitators, inhibitors and benefits of e-transformation and also presents challenges and key lessons learned.

Keywords: e-transformation, aviation industry, digital information

1 Introduction

Although the possibility of a digital cockpit became apparent a decade ago, aeronautical information in the air and on the ground is still largely paper based. However, the digital cockpit is starting to become commonplace. This study investigates the digital transformation of the aviation industry and the influence of the technological, organizational and environmental (TOE) context. Using the TOE framework, we seek theoretical answers to the following research questions:

- What are the drivers and benefits of the e-transformation?
- What challenges accompany the digital transformation?
- What are the facilitators and inhibitors of e-transformation?

We also analyze the challenges and present lessons learned.

2 Technology–Organization–Environment (TOE) framework

The original technology–organization–environment (TOE) framework was developed for the adoption of innovations (Tornatzky & Fleischer, 1990). IS researchers have used the TOE framework to analyze EDI, open systems and e-business adoption (Chau and Tam 1997, Iacovou, Benbasat and Dexter 1995, Kuan and Chau 2001, Zhu et al. 2002, 2003). The model in this study in Figure 1 adapts the TOE framework (Tornatzky & Fleischer, 1990) and the derived e-

business model (Zhu et al. 2002, 2003) to analyze e-transformation. In the next three sections, the paper examines the relevant research literature on the technological context, organizational context and the environmental context.
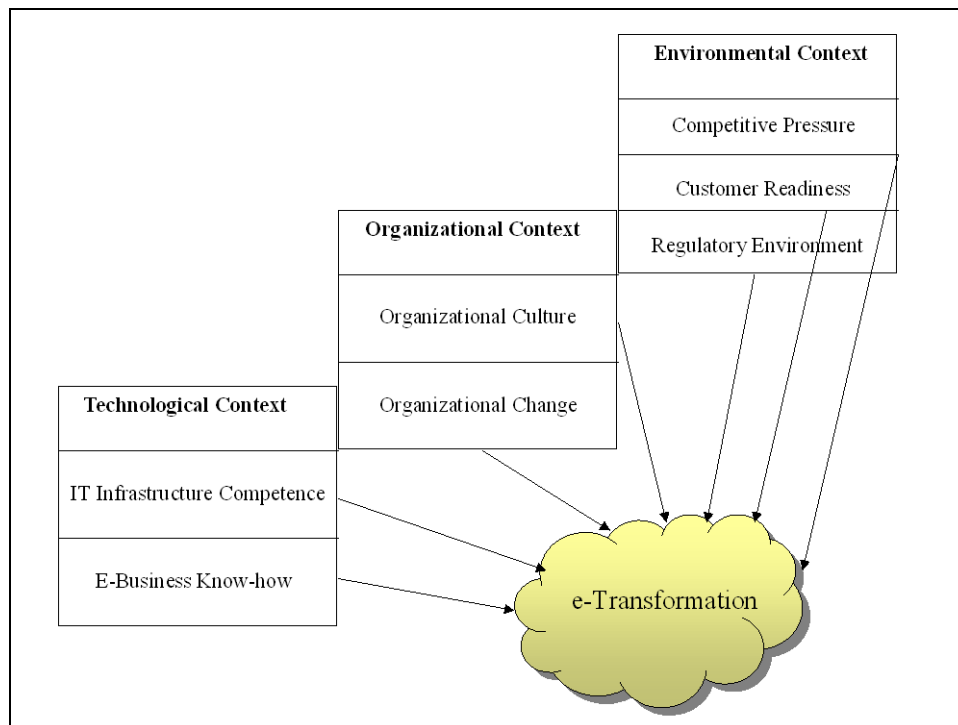
Figure 1: e-Transformation Model

2.1 Technological context

This context includes internal technologies and available technologies in the market (Zhu et al. 2002). Internally, e-transformation relies on competent employees who can manage an appropriate technical infrastructure and have e-business know-how. Externally, e-business technology availability is necessary.

2.1.1 Information Technology Infrastructure competence

Organizational readiness for adoption of an innovation is dependent on technical skills (Iacovou, Benbasat and Dexter 1995). A strong IT staff has high technical skills and interpersonal skills, which enable an effective partnership between IT and business management (Feeny and Willcocks 1998, Ross, Beath and Goodhue 1996). The partnership ensures that the infrastructure will support e-business and traditional business requirements. Core IS capabilities build and leverage technology assets and plan an IT architecture (Feeny and Willcocks 1998). Firms need a well-defined architecture, standards, and a reusable technology base (Ross, Beath and Goodhue 1996).

2.1.2 e-Business know how

Knowledge of managing e-business is e-business know how (Zhu et al. 2002, 2003). It is often intangible and difficult to imitate. Web experience influences Web assimilation since technology competence is essential for getting value from e-business (Chatterjee, Grewal and Sambamurthy 2002). Dynamic capabilities,

such as choosing new IT, matching economic opportunities with available technology, executing business innovation for growth, assessing customer value, recognizing opportunities and developing absorptive capacity influence Net-Enablement (Wheeler 2002, Zahra & George 2002). Furthermore, an iterative "change, measure, learn" approach using a Capability Maturity Model (CMM) framework transforms software development processes to accommodate the e-business environment (Garud, Kumaraswamy and Sambamurthy 2006).

2.2 Organizational context

Prior studies assessed the organization context in terms of firm size; the centralization, formalization, and complexity of its managerial structure; the quality of its human resource; and the amount of slack resources available internally (Zhu et al. 2002). We focus at the organizational level, on the openness of organizational culture to innovation and processes that accommodate change as being essential factors for e-transformation.

2.2.1 Organizational culture

Organizational culture is associated with the organization's sense of identity, its goal or core values, its primary ways of working and a set of shared assumptions (Schein 1992). Organizational culture does not change easily (Leidner and Kayworth 2006). Older firms usually favor the status quo and have structural inertia from entrenched processes, which hinder metastructuring actions that promote web assimilation through renewed cognitions, norms, and rules (Chatterjee, Grewal and Sambamurthy 2002). Consequently, organizational age is likely to slow down e-transformation and Web assimilation.

2.2.2 Organizational change processes

History has recorded organizations that could not adapt to innovation (Christensen 1997). Such organizations typically had entrenched processes. Changing entrenched processes depends on leadership to communicate the urgency for change and the vision for the transformed organization. As e-business proliferates, the strategic emphasis shifts from physical capabilities to knowledge based capabilities (Burn & Alexander 2005). The workforce needs to transform its mindset and depends on leadership to facilitate the organizational change. Perceived benefits will encourage adoption of an innovation (Iacovou, Benbasat and Dexter 1995). Perceived direct benefits of EDI include elimination of paperwork, labor savings, faster processing and increased timeliness. Perceived opportunities from EDI include increased operational efficiency, better customer service and increased ability to compete.

2.3 Environmental context

An organization's industry, competitors, access to resources, and dealings with government are part of the environmental context (Iacovou, Benbasat and Dexter 1995, Tornatzky and Fleischer 1990, Zhu et al. 2002). Competitive pressure, the regulatory environment and lack of customer readiness are environmental influences on e-transformation.

2.3.1 Competitive pressure

Competitive pressure drives e-business adoption (Iacovou, Benbasat and Dexter 1995, Zhu et al. 2003). The type of industry makes a difference (Chatterjee, Grewal and Sambamurthy 2002). Drivers of digital transformation include electronic deliverability, information intensity, customizability, aggregation effects, real-time interface and missing competencies (Andal-Ancion, Cartwright & Yip 2003). Electronic deliverability may trigger changes in industry structure (Amit and Zott 2001). In the photography industry, despite a decade of transformation effort Kodak has suffered from competitive cost pressure on its digital products and services simultaneous with a large drop in demand for its traditional products (Barrett and Carr 2004). Customizability of new e-products and e-services can lock in customers by presenting a tailored solution rather than a generic portfolio of products and services. Similarly, a real-time interface and aggregation effects, through integration of complementary products and services, such as brick-and-click synergy (Gulati & Garino 2000, Ranganathan, Goode & Ramaprasad 2003), also have the potential to add value and lock in customers (Amit and Zott 2001).

2.3.2 Regulatory environment

The regulatory environment can both promote and slow e-business adoption and e-transformation. Government and industry regulations can force resources to be allocated for compliance. For example, government imposed Sarbanes-Oxley compliance has diverted resources for public traded companies and large automobile manufacturers imposed EDI adoption on suppliers (Iacovou, Benbasat and Dexter 1995). Similarly, Wal-Mart imposed RFID adoption on its suppliers. However, imposed standards are problematic if resources are not available. Moreover, standards are often slow to evolve because of the need to reach consensus. For example, Kodak's work on technical standards to help it compete in digital photography is progressing slowly (Barrett and Carr 2004).

2.3.3 Customer readiness

Customer readiness for e-business will affect adoption of the innovation since B2B
e-business depends on interorganizational relationships (Iacovou, Benbasat and Dexter 1995, Zhu et al. 2003). Readiness will determine the potential market volume and profitability for vendors (Zhu et al. 2003). Organizations need financial resources to purchase assets such as EDI software and telecommunication hardware (Iacovou, Benbasat and Dexter 1995).

2.4 Integration of Technology–Organization–Environment Contexts

The three contexts are inter-related. Organizational readiness depends on financial readiness and technological readiness (Iacovou, Benbasat and Dexter 1995). Organizational culture and change processes will determine organizational readiness to adopt the innovation and transform. Information technology infrastructure competence and e-business know-how will also determine readiness. Such readiness will affect the industry environment.

In the following sections, we apply the TOE model and the literature to e-transformation in the aviation industry and conclude with lessons learned and implications for research and practice.

3   Drivers of e-Transformation in the Aviation Industry

The aviation industry is unique in some respects. Yet many of the drivers mentioned in the e-business literature are applicable. See Table 1 for drivers of e-transformation that are relevant to the aviation industry.

Table 1: Drivers of digital transformation relevant to the aviation industry

Drivers of digital transformation	Relevance to the aviation industry
Electronic deliverability	Charts and navigation data are electronically deliverable
Information intensity	Charts and navigation data have high information intensity
Customizability	Company portals enable customizability
Aggregation effects	Customers purchase aggregated products and services
Real-time interface	Portals provide a real-time interface

4   Digital Products and Services

Digital products and services in the aviation industry include the electronic flight bag (EFB) and associated ground tools, charts and navigation data (Allen 2003, FAA 2003, Hughes 2004, Intel 2005, Thomas 2006). Charts and navigation data are electronically deliverable and have high information intensity making them ideal for e-business. A portal for each airline makes the digital products and services amenable to customizability, aggregation effects and delivery through a real-time interface. An EFB provides a scalable, open-architecture platform that allows the airline to add its own documents or third-party applications (PR Newswire 2007).

4.1   Electronic Flight Bag

The EFB assists pilots in pre-flight preparation, aircraft flight, and post-flight debriefs. It calculates performance figures, displays charts, improves taxi positional awareness, provides video flight deck entry surveillance, and allows electronic access to documents (Allen 2003). Economic pressures to eliminate or reduce the amount of paper carried in the flight deck are triggered by the fact that every extra gram of weight carried in an airplane must be paid for in extra fuel consumption and that space is very limited (Nomura and Hutchins 2006). A decade ago, the airlines started thinking about eliminating the 70 lbs of paper charts and documents that pilots must carry on board to save weight and reduce clutter. They began to look at digital transformation strategies to reduce fuel and maintenance costs and streamline flight services operations. The 'paperless flight

deck' also promises advances in efficiency and taxiway and flight deck safety (Allen 2003, Flight Safety Foundation 2005, Hughes 2004). There are three EFB configurations: Class 1 which is portable, Class 2 which is semiportable, and Class 3 which is installed avionics (Allen 2003, FAA 2003, Hughes 2004).

5 Technological context

This section analyzes the information technology infrastructure competence and e-business know how relevant in the airline industry.

5.1 Information Technology Infrastructure competence

Airlines need to have the infrastructure, training, systems and ability to develop additional content to take full advantage of the EFB capabilities and reap the benefits of a paperless cockpit (Search Asia Travel Tips 2006). Communications infrastructure challenges need to be overcome (Overby 2006). FedEx, one of the first airlines to bring laptops into the cockpit in 1991 to quickly calculate and recalculate aircraft performance, is the lead airline for information infrastructure competence (Croft 2004). Its Totally Integrated Technical Aircraft Network (TITAN) is an information infrastructure of EFBs, file servers and transceivers that provide a high bandwidth wireless connection between the onboard system and the ground. It allows digital information, including manuals and minimum equipment lists, to flow between the aircraft and the ground during all phases of a flight, anywhere in the world. Future possibilities with the TITAN infrastructure include equipping all aircraft with wireless digital cameras so that load managers can monitor loading progress or problems; or sending videos of maintenance procedures to a remote location to show a mechanic how to perform a task. TITAN helps keep FedEx's aircrafts safe and on schedule.

5.2 e-Business know how

Although airlines have sophisticated e-business know how for ticket reservations, Internet delivery of digital navigational and operational information is part of the new paradigm in the industry. They need e-business know-how to assess the EFB value proposition, to recognize the opportunity, to leverage customization features and to deploy digital delivery of updated information. For example, Northwest Airlines expects by transitioning to S1000D standards it will gain common document delivery for all aircraft, reuse of contents in job cards, common interfaces to inventory, forecasting and scheduling maintenance systems and better delivery over the web (Canaday 2006).

6 Organizational context

The transformation impacts most airline industry employees, especially pilots and ground operations staff. Organizational culture and organizational change processes illustrate the process of e-transformation.

6.1 Organizational culture

Pilots and airlines welcome fewer workers' compensation problems relating to lugging flight bags around (Hughes 2004, Intel 2005, Thomas 2006).

Additionally, pilots complain that maintaining their bags by hand filing up-to-date information is tedious and time-consuming. This labor and the added weight of the flight bag itself add to the cost of each flight. Also the expense of printing paper documents and distributing them to pilots adds significant costs. Nevertheless, pilots might not be enthusiastic about using an EFB. According to some experts, the proliferation of EFB features and vendors creates human factors and training issues (Allen 2006). An ethnographic study reveals that a completely paperless cockpit might not be advantageous (Nomura, Hutchins and Holder 2006). Paper is an integral feature of using new technologies and plays important social interaction roles in crew coordination, message confirmation, note-taking, and information affordance. The target of design activity should be the cognitive functions performed in the flight deck. Concerns include the aviation expertise level of young pilots when too much automation keeps them from getting involved in deep tasks and understanding deeply about the airplane's behavior in any flight context. Instead, the ideal solution would allow paper to complement the digital products and services. Similar to brick-and-click synergy (Gulati & Garino 2000, Ranganathan, Goode & Ramaprasad 2003), paper and digital products have potential synergy.

6.2 Organizational change processes

Organizational inertia makes it difficult to change entrenched processes. Also the industry is conservative because of safety concerns, despite the claims that the EFB improves taxiway and flight deck safety from taxi positional awareness and video flight deck entry surveillance (Allen 2003, Flight Safety Foundation 2005, Hughes 2004, Intel 2005, Seidenman and Spanovich 2006, Thomas 2006). When the perceived benefits significantly outweigh the costs, e-transformation will accelerate. Potential cost savings data based on EFB workshops held with 10 different airlines for 30 operational processes, including maintenance, fuel, catering and airport turn-times, showed an annual savings of between $50,000 and $200,000 per aircraft (Seidenman and Spanovich 2006). For example, there is potential for 75 percent savings from reductions in task times, through the elimination of paper and creation of an electronic audit trail; and a 40 percent timesaving in airport turn-times. The goal is to provide a benefit to cost ratio of 2-1 to 5-1 over a five-year period, including a one- to two-year payback period.

7 Environmental context

Environmental influences on e-transformation are competitive pressure, the regulatory environment and lack of customer readiness.

7.1 Competitive pressure

Since the aviation industry is highly competitive, opportunities for cost savings are in demand. Although EFBs have implementation and infrastructure costs (Overby 2006), operating cost savings could be as high as 5% (Thomas 2006). EFBs can help reduce fuel and maintenance costs (Allen 2003, Intel 2005, Search Asia Travel Tips 2006, Seidenman and Spanovich 2006). EFBs instantly calculate an airplane's ideal speed and engine settings in any weather on any runway with any payload (Thomas 2006). Such calculations can increase the payload of a 777 taking off from a wet runway by up to 20,000 pounds. EFBs provide a

comprehensive maintenance diagnostic capability for tracking parts and aircraft condition. Finally, EFBs reduce workers' compensation problems relating to lugging flight bags around (Intel 2005, Thomas 2006).

7.2 Regulatory environment

Increasingly complex corporate and governmental regulations slow down industry transformation. The aviation industry is highly regulated because of safety issues. Regulation was an obstacle to widespread EFB adoption until the Federal Aviation Authority (FAA) issued guidelines (FAA 2003, Intel 2005). FAA Advisory Circular 120-76A governing the digital transition provides for three different levels of software and three classes of "electronic flight bag" hardware to run and display the data (FAA 2003, Hughes 2004).

Class 1 EFB is a totally portable system requiring no certification because it is not installed in the aircraft (FAA 2003, Hughes 2004, Seidenman and Spanovich 2006). Type A software usually is available on Class 1 hardware and is generally used for viewing electronic documentation (Croft 2003). Class 2 EFB, although portable, needs an FAA installation approval to connect to the aircraft's power and databuses (FAA 2003, Hughes 2004, Seidenman and Spanovich 2006). Type B software usually is available on Class 2 hardware and is used for viewing charts as well as electronic documentation (Croft 2003). A Class 3 EFB requires Aircraft Certification Service installation approval since it is an integral, permanent part of the aircraft's avionics system (FAA 2003, Hughes 2004, Seidenman and Spanovich 2006). Type C software usually is available on Class 3 hardware and can display own-ship position and communicate with other aircraft systems such as the engines (Croft 2003).

7.3 Customer readiness

Customer readiness for e-transformation varies in the different sectors of the industry. The customers for digital information in the aviation industry include private small planes, charter airlines, commercial airlines and the military. Adoption of the EFB has been fastest by private small plane owners since they are not subject to as many safety regulations as charter airlines, commercial airlines and the military. Business jet operators adopted EFBs earlier due to a lesser degree of FAA regulation compared to commercial airlines (Hughes 2004, Thomas 2006). Fractional business jet operator Flight Options was one of the first to outfit its entire fleet with Class 2 EFBs in mid-2000. Flight Options claims it has saved millions of dollars because its typical pilot saves 4 hours on an eight-day rotation by not having to do paper revisions (Hughes 2004). Most commercial airlines found it more difficult to justify the technology due to implementation costs and communications infrastructure challenges (Overby 2006). However, Southwest Airlines has been using Fujitsu laptops for takeoff number-crunching and FedEx pilots have been using HP Omnibooks since 1991 to perform last-minute takeoff calculations (Thomas 2006). Thousands of Class 1 and Class 2 EFBs are in operation, and the first Class 3 unit was deployed in October 2003 on a KLM 777-200ER. Since then, several other carriers have followed. For example, Continental as part of its companywide initiative to be paperless wherever possible, accepted delivery of its first Class 3 EFB-equipped 777-200ER in March 2007 (PR Newswire 2007).

8 Integration of Technology–Organization–Environment

The three contexts are inter-related in the airline industry. Similarly, environments such as EDI and open systems, which have been analyzed using the TOE framework, find interdependencies among the technological, organizational and environmental contexts. For example, organizational readiness for EDI in small firms depends on their financial readiness and technological readiness to attain the required level of IT sophistication (Iacovou, Benbasat and Dexter 1995). In the airline industry, readiness for e-transformation depends on financial readiness to invest in the EFB. Organizational culture and change processes will determine organizational readiness to adopt the EFB innovation and transform the industry. Information technology infrastructure competence and e-business know-how will determine technological readiness. Such readiness will affect the airline industry environment overall.

9 Lessons Learned

Many of the lessons learned are generalizable and applicable to e-transformation for other industries.

- Drivers for industry e-transformation stem from the need to control costs, competitive pressure and technological opportunities. The manual chart maintenance process is too labor intensive and time consuming. Competitive pressure motivates cost reduction and increased operational efficiency. Organizations also want to leverage technological opportunities.
- The electronic deliverability, information intensity, customizability, aggregation effects drivers leverage inherent characteristics of airline information and services (Andal-Ancion, Cartwright & Yip 2003)
- Benefits of e-transformation include streamlined flight services operations and efficiency from electronic access to documents, displays of charts and calculation of performance figures (Allen 2003, Flight Safety Foundation 2005, Hughes 2004). Reduced fuel and maintenance costs are from less paper on board, which saves weight to enable better fuel consumption and reduces clutter to enable better use of limited space (Allen 2003, Intel 2005, Nomura and Hutchins 2006, Search Asia Travel Tips 2006, Seidenman and Spanovich 2006). Taxiway and flight deck safety improves from taxi positional awareness and video flight deck entry surveillance (Allen 2003, Flight Safety Foundation 2005, Hughes 2004, Intel 2005, Seidenman and Spanovich 2006, Thomas 2006).
- Paper can complement the digital products and services (Nomura, Hutchins and Holder 2006). Paper is an integral feature of using new technologies and plays important social interaction roles in crew coordination, message confirmation, note-taking, and information display.
- Organizations need to prepare for technological innovation. To realize the benefits including new revenue opportunities, cost savings and increased efficiency, organizations need to change their strategy, culture and processes.
- Management needs to communicate the new vision to prepare employees for the change.

- Facilitators for e-transformation include leadership, resource allocation and organizational learning.
- Inhibitors include cultural inertia, entrenched processes, lack of customer readiness and regulation. Organizations facilitate customer readiness with training, trade shows, and involvement on regulatory committees.
- Challenges include developing new capabilities, and achieving mature repeatable digital processes.

10 Conclusion

The TOE analysis of e-transformation reveals that the airline industry has successfully begun its journey. Driven by the need to control costs for maintenance of chart manuals, the industry has started to shift the distribution process to electronic delivery. At the same time, competitive pressures and improving technological competence and e-business know-how have driven the industry to start adopting the EFB and other digital products and services. However, prior to 2003 the transformation was slower than expected, partly because the FAA and regulatory environment was cautious about safety issues and not ready for radical change. The expected demand for the EFB is expected to explode in 2008 with the introduction of the next generation of airplanes, which incorporate the EFB in their design (Seidenman and Spanovich 2006). Challenges include developing the IT infrastructure, optimizing new digital processes and cultural transformation. Organizations in the industry need to be ambidextrous to leverage their stability and domain expertise while moving towards a flexible digital paradigm.

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