Case Study – Denver International Airport Baggage Handling System – An illustration of ineffectual decision making

Calleam Consulting Ltd – Why Technology Projects Fail

Synopsis

Dysfunctional decision making is the poison that kills technology projects and the Denver Airport Baggage System project in the 1990's is a classic example. Although several case studies have been written about the Denver project, the following paper re-examines the case by looking at the key decisions that set the project on the path to disaster and the forces behind those decisions.

Background

What was to be the world's largest automated airport baggage handling system, became a classic story in how technology projects can go wrong. Faced with the need for greater airport capacity, the city of Denver elected to construct a new state of the art airport that would cement Denver's position as an air transportation hub. Covering a land area of 140 Km^2, the airport was to be the largest in the United States and have the capacity to handle more than 50m passengers annually [1,2].

The airport's baggage handling system was a critical component in the plan. By automating baggage handling, aircraft turnaround time was to be reduced to as little as 30 minutes [1]. Faster turnaround meant more efficient operations and was a cornerstone of the airports competitive advantage.

Despite the good intentions the plan rapidly dissolved as underestimation of the project's complexity resulted in snowballing problems and public humiliation for everyone involved. Thanks mainly to problems with the baggage system, the airport's opening was delayed by a full 16 months. Expenditure to maintain the empty airport and interest charges on construction loans cost the city of Denver $1.1M per day throughout the delay [3].

System at a glance:

1. 88 airport gates in 3 concourses
2. 17 miles of track and 5 miles of conveyor belts
3. 3,100 standard carts + 450 oversized carts
4. 14 million feet of wiring
5. Network of more than 100 PC's to control flow of carts
6. 5,000 electric motors
7. 2,700 photo cells, 400 radio receivers and 59 laser arrays

The embarrassing missteps along the way included an impromptu demonstration of the system to the media which illustrated how the system crushed bags, disgorged content and how two carts moving at high speed reacted when they crashed into each other [4]. When opening day finally arrived, the system was just a shadow of the original plan. Rather than automating all 3 concourses into one integrated system, the system was used in a single concourse, by a single airline and only for outbound flights [5]. All other baggage handling was performed using simple conveyor belts plus a manual tug and trolley system that was hurriedly built when it became clear that the automated system would never achieve its goals.

Although the remnants of the system soldiered on for 10 years, the system never worked well and in August 2005, United Airlines announced that they would abandon the system completely [6]. The $1 million per month maintenance costs exceeded the monthly cost of a manual tug and trolley system.

Chronology of events:

Denver International Airport (DIA) Baggage System Development Timeline [1, 2, 3, 4, 5, 6]

Nov 1989	Work starts on the construction of the airport
Oct 1990	City of Denver engages Breier Neidle Patrone Associates to analyse feasibility of building an integrated baggage system. Reports advises that complexity makes the proposition unfeasible
Feb 1991	Continental Airlines signs on and plans on using Denver as a hub
Jun 1991	United Airlines signs on and plans on using Concourse A as a hub
Jun 1991	United Airlines engages BAE Systems to build an automated baggage system for Concourse A. BAE was a world leader in the supply, installation and operation of baggage handling equipment
Summer 1991	Airport's Project Management team recognizes that a baggage handling solution for the complete airport was required. Bids for an airport wide solution are requested
Fall 1991	Of the 16 companies included in the bidding process only 3 respond and review of proposals indicate none could be ready in time for the Oct 1993 opening. The 3 bids are all rejected
Early 1992	Denver Airport Project Management team approach BAE directly requesting a bid for the project
Apr 1992	Denver Airport contracts with BAE to expand the United Airlines baggage handling system into an integrated system handling all 3 concourses, all airlines, departing as well as arriving flights. In addition system is to handle transfer baggage automatically. Contract is hammered out in 3 intense working sessions
Aug 1992	United Airlines changes their plans and cuts out plans for the system to transfer bags between aircraft. Resulting changes save $20m, but result in a major redesign of the United Airlines portion of the system. Change requests are raised to add automated handling of oversized baggage and for the creation of a dedicated ski equipment handling area
Sep 1992	Continental requests ski equipment handling facilities be added to their concourse as well
Oct 1992	Chief Airport Engineer, Walter Singer dies. Mr Singer had been one of the driving forces behind the creation of the automated baggage system
Jan 1993	Change orders raised altering size of ski equipment claim area and adding maintenance tracks so carts could be serviced without having to be removed from the rails
Feb 1993	Target opening date shifted from 31 Oct 93 to 19 Dec 93 and soon thereafter to 9 Mar 94
Sep 1993	Target opening date is shifted again, new target date is 15 May 1994
31 Oct 1993	Original target for opening
19 Dec 1993	Second target for opening
Jan 1994	United Airlines requests further changes to the oversize baggage input area
9 Mar 1994	Third target for opening
Mar 1994	Problems establishing a clean electrical supply results in continual power outages that disrupt testing and development. Solution requires installation of industrial filters into the electrical system. Ordering and installation of the filters takes several months
Apr 1994	Airport authorities arrange a demonstration for the system for the media (without first informing BAE). Demonstration is a disaster as clothes are disgorged from crushed bags
Apr 1994	Denver Mayor cancels 15 May target date and announces an indefinite delay in opening
May 1994	Logplan Consulting engaged to evaluate the project
15 May 1994	Fourth target for opening
May 1994	BAE Systems denies system is malfunctioning. Instead they say many of the issues reported to date had been caused by the airport staff using the system incorrectly
Aug 1994	System testing continues to flounder. Scope of work is radically trimmed back and based on Logplan's recommendation airport builds a manual tug and trolley system instead
Aug 1994	City of Denver starts fining BAE $12K per day for further delays
28 Feb 1995	Actual opening
Aug 2005	In order to save costs the system is scrapped in favour of a fully manual system. Maintenance costs were running at $1M per month at the time.

Basic Mode of Failure

As with all failures the problems can be viewed from a number of levels. In its simplest form, the Denver International Airport (DIA) project failed because those making key decision underestimated the complexity involved. As planned, the system was the most complex baggage system ever attempted. Ten times larger than any other automated system, the increased size resulted in an exponential growth in complexity. At the heart of the complexity lay an issue know as "line balancing" [1]. To optimize system performance, empty carts had to be distributed around the airport ready to pick up new bags. With more than 100 pickup points (check in rows and arrival gates) each pickup needed to be fed with enough empty carts to meet its needs. The algorithms necessary to anticipate where empty carts should wait for new bags represented a nightmare in the mathematic modeling of queue behaviours. Failure to anticipate the number of carts correctly would result in delays in picking up bags that would undermine the system's performance goals.

Failure to recognise the complexity and the risk involved contributed to the project being initiated too late. The process of requesting bids for the design and construction of the system was not initiated until summer of 1991 [7]. Based on the original project schedule, this left a little over two years for the contracts to be signed and for the system to be designed, built, tested and commissioned. The closest analogous projects were the San Francisco system and one installed in Munich. Although much smaller and simpler, those systems took two years to implement [7]. Given the quantum leap in terms of size and complexity, completing the Denver system in two years was an impossible task.

The underestimation of complexity led to a corresponding underestimation of the effort involved. That underestimation meant that without realising it, the Project Management team had allowed the baggage system to become the airport's critical path. In order to meet the airport's planned opening date, the project needed to be completed in just two years. This clearly was insufficient time and that misjudgement resulted in the project being exposed to massive levels of schedule pressure. Many of the project's subsequent problems were likely a result of (or exacerbated by) shortcuts the team took and the mistakes they made as they tried to meet an impossible schedule.

Key Decisions that Led to Disaster

Although the basic mode of failure is fairly clear, to understand the root cause and what should have been done differently we need to examine how the critical decisions that triggered the failure were made. Project failures usually involve numerous flawed decisions, but within those many missteps, certain key decisions are the triggers that set in motion the sequence of events that lead to disaster.

Key Decision 1 – A change in strategy

At the start of a project strategic decisions are made that set the project's direction. In the DIA case, a strategic error was made that resulted in "flip-flop" being made part way through the project.

Prior to requesting bids for an integrated system in the summer of 1991, the airport's Project Management team had assumed that individual airlines would make their own baggage handling arrangements [5]. United Airlines had indeed proceeded with their own plan by engaging BAE (Boeing Airport Equipment Automated Systems Incorporated) directly. Continental Airlines had however not made any arrangements and given that the airport was not yet fully leased out, other sections of the airport were not being addressed.

In the summer of 1991, the airport's Project Management team changed their strategy and realised that if an integrated system was to be built, they needed to take responsibility back from the individual airlines and run the project themselves. This change in strategy came a little more than two years prior to the airport's planned opening date and the timing of the decision was in large part the trigger behind the excessive schedule pressure the project was exposed to.

In one way the change in strategy made sense because an integrated system required centralized control and the airport's Project Management team was the only central group that could run the project. Clearly the timing of the decision was however extremely poor. Had the correct strategy been set at the outset, there would have been two additional years in which to develop the system. Those two years may well have been enough to allow designers to understand the complexity issue more deeply and to find ways to either overcome it or agree with the stakeholders on a simpler design.

The delay in setting the correct strategy is likely rooted in the history of how prior airport construction projects had been run. Because earlier generation baggage facilities were dedicated to individual airlines, airlines had historically built their own systems when a new airport was built [5]. The advent of the integrated airport wide system required a change in mindset. The integrated nature of the new systems meant that instead of airlines looking after their own facilities, airport's needed to take control.

The key point the airport's Project Management team failed to see was that the shift in technology required a corresponding shift in organizational responsibilities. The failure to recognise that shift represents a planning failure that dated back to the very start of the construction project. The public record does not detail how the original strategy was set or even if the topic had been directly considered. However, people typically see the world through the eyes of their prior experiences and given that almost all prior airport projects had left this responsibility to the airline, it is very likely that the question was simply never discussed.

In broader terms, the mistake made was a failure to link the airport's overall strategy (the goal of having one of the world's most efficient airports) with the sub-strategy of how to build the baggage system. The mode in which that failure occurred may well simply have been a failure to ask the critical question of where responsibility for development of the baggage system needed to be.

Key Decision 2 – The decision to proceed

Although the change in strategy is somewhat understandable, what is less understandable is why both the airport Project Management team and BAE decided to proceed with the full scale project despite clear indications that there was insufficient time left for the project to be completed successfully.

Prior to entering into the BAE contract, there were at least three indications that the project required more than two years or was simply not feasible;

1. The 1990 Breier Neidle Patrone Associates report indicated the complexity was too high for the system to be built successfully [1],

2. Analysis of the three bids received indicated that none of the vendors could build the system in time for the Oct 1993 opening [4],
3. Experts from Munich airport advised that the much simpler Munich system had taken 2 full years to build and that it had run 24 / 7 for 6 months prior to opening to allow bugs to be ironed out [5].

Reports indicate that the decision to proceed was based on the communications between the airport's Chief Engineer (Walter Slinger) and BAE's Senior Management team. While BAE had initially chosen not to bid for the airport wide contract, the rejection of the three official bids resulted in the airport team speaking directly to BAE about the possibility of expanding the United Airlines system that was already under development. Those discussions resulted in the preparation of a specification and the creation of a large scale prototype (reported to have filled up a 50,000 sq ft warehouse) [7]. Demonstration of the prototype to is said to have been the factor that convinced Slinger that the system was feasible.

Despite the fact that BAE was talking directly to Slinger about the possibility of building the system, some reports indicate that within BAE several managers were voicing concern. Again the issues related to whether or not it was feasible to build such a large system in such a short period of time. Reports indicate that several managers advised the BAE Senior Management team that the project was at minimum a four year project, not a two year project [5].

The failure by both Slinger and BAE's Senior Management team to heed the advice they were receiving and the failure of the airport's Project Management team to have the BAE proposal and prototype independently reviewed is the epicentre of the disaster.

Although published reports do not indicate why the expert advice was ignored, it is clear that both Slinger and BAE's Senior Management team underestimated the complexity of the project and ignored information that may have corrected their positions. Many factors may have led them into that trap and likely issues that may have influenced the decision making include;

1. From Slinger's perspective
    a. Denver was to be a state of the art airport and as such the desire to have the most advanced baggage system would likely have been a factor behind Slinger's willingness to proceed,
    b. Slinger's prior experiences with baggage handling will have been based on simple conveyor belts combined with manual tug and trolley systems. Those prior experiences may have led Slinger to underestimate the complexity of moving to a fully automated system,
    c. As a Civil Engineer, Slinger was used to the development of physical buildings and structures rather than complex technology systems, this may have predisposed him to underestimate the mathematical complexity associated with an issue such as "line balancing",
    d. Slinger is reported to have been a hands-on leader who liked to solve problems himself. As such Slinger may have been inclined to make decisions on his own rather than seeking independent advise,
    e. Slinger dealt with the discussions with BAE personally, given that he was responsible for the complete airport, he will have had considerable other duties that would have limited the amount of time he had to focus on the baggage system,
    f. On the surface the prototype may well have made it look as if BAE had overcome the technical challenges involved in building the system and as such Slinger may have been lured into a false sense of security.
2. From BAE's perspective
    a. The project was a big revenue opportunity and represented a chance to grow the business,

   b. The prestige of securing the DIA contract would position BAE to secure other large contracts around the world. New airports or terminals were planned for Bangkok, Hong Kong, Singapore, London and Kuala Lumpur and BAE would be a strong contender if they could win the DIA project.
3. Other factors
   a. Both BAE and Slinger will have recognized that they were working within a tight timeframe and the pressure to move quickly may have caused them to put due diligence to one side.
   b. The belief that due to the airport's size, a manual system would not be fast enough to meet aircraft turnaround requirements. Note however that this belief was unfounded as the airport functions happily today using a manual system.

Key Decision 3 – Schedule, scope and budget commitments

The schedule, budget and scope commitments a team enter into are amongst the most critical decisions they will make. The seeds of project success or failure often lie in the analysis that goes into making those decisions and the way such commitments are structured.

In the DIA case, BAE committed to deliver the complete system under a fixed scope, schedule and budget arrangement. The decision to give a firm commitment to scope, schedule and budget transferred considerable risk onto BAE's shoulders. This move indicates strongly that those in the highest level of BAE's management structure had completely failed to recognize the level of risk they were entering into. Had they been more aware, they almost certainly would have taken steps to limit the risk and to find ways to limit the scope to something that was more achievable in the time available.

Again the finger prints of excessive schedule pressure can be seen in the commitments BAE entered into. The contractual conditions for the agreement and the scope of work were hammered out in just three *"intense"* working sessions [7]. Although BAE had some level of understanding because of their contract with United Airlines, clearly the three working sessions will not have provided sufficient time for the different parties to develop an in-depth understanding of what was involved or for them to fully understand the risks they were taking.

BAE and the airport Project Management team made another major mistake during the negotiations. Although the airlines were key stakeholders in the system they were excluded from the discussions. Excluding stakeholders from discussions in which key project decisions are made is always a losing strategy. When previously excluded stakeholders are finally engaged, they usually ask for significant changes that can negate much of the previous work done on the project.

Key Decision 4 – Acceptance of change requests

Not surprisingly, as the project progressed the airlines did indeed ask for a number of significant changes. Although in the original negotiations, BAE had made it a condition that no changes would be made, the pressure to meet stakeholder needs proved to be too strong and BAE and the airport's Project Management team were forced into accepting them. Among the major changes were; the adding of ski equipment racks, the addition of maintenance tracks to allow carts to be serviced without being removed from the rails and changes to the handling of oversized baggage. Some of the changes made required significant redesign of portions of work already completed.

Accepting these changes into a project that was already in deep trouble raises some further troubling questions. Did the team fail to understand the impact the changes might have? Did they fail to recognise how much trouble the project was already in? Although answers to those questions are not available from the public record, the acceptance of the change requests again hints at the communications disconnects that were occurring inside the project. Clearly some of the people involved will have understood the implications, but those voices appear not to have connected with those who were making the overall decisions.

Key Decision 5 – Design of the physical building structure

Rather than being separate entities, the baggage system and the physical building represented a single integrated system. Sharing the physical space and services such as the electrical supply the designers of the physical building and the designers of the baggage system needed to work as one integrated team.

Largely because the design of the building was started before the baggage system design was known, the designers of the physical building only made general allowances for where they thought the baggage system would go. When the baggage system design was eventually started, the baggage system design team was forced to work within the constraints left to them by the designers of the physical building (estimates to change the physical structure to suit the needs of the baggage system are reported to have been up to $100M).

The resulting design meant that the baggage system had to accommodate sharp turns that were far from optimal and increased the physical loads placed on the system [1]. Those stresses were key contributors to the system's reliability problems. In particular, navigating sharp turns is reported to have been one of the major problems that lead to bags being ejected from their carts. These problems ultimately proved so severe that the speed of the system was halved from 60 cars per minute to 30 cars in order to reduce the physical forces when negotiating tight turns. That quick fix however had the side affect that it began to undermine the performance goals the system was trying to meet.

Although the designers of the physical building likely did their best to make allowance for the baggage system, this portion of the story once again illustrates a breakdown in the overall planning of the project. The allowance of spaces in which the baggage system would operate represented a key interface between the design of the physical building and the baggage system. To make effective decisions about how to design the physical building, the designers of the physical building needed to be working alongside people who had expertise in designing baggage systems. Clearly this did not happen. What is not clear is if the designers of the physical building requested such expertise be provided or if they just went ahead in isolation. In either case, the Project Management team should have recognised the significance of the interface between the baggage system and the physical building and arranged for the appropriate people to work together.

Key Decision 6 – The decision to seek a different path

Following the embarrassing public demonstration to the press in Apr 1994, the Mayor of Denver recognized that the project was in deep trouble. The demonstration had been an unmitigated disaster and pressure was building from various sources pushing the Mayor to intercede. When the Mayor did step in, Mattias Franz of Logplan Consulting of Germany (a specialist in the design and construction of baggage handling systems) was called in to review the situation [9]. Despite United Airlines instance that the automated system be finished, based on Logplan's recommendation the Mayor slashed project and ordered that a manual trolley system built at an additional cost of $51M [8].

While the Mayor was correct in taking action, the timing of the intervention again reveals something about the internal dynamics of the project. By the time the Mayor took action, the airport was already 6 months behind schedule and four opening dates had already been missed. In addition the disastrous demonstration of the system had shown to the world how bad the state of the project really was.

The four missed opening dates and the disastrous demonstration indicate that those at the highest level really had little idea what the true status of the project was. Bringing in an external consultant to review the project was certainly a good decision, but again it was a decision that was made far too late. A project of this size, complexity and risk should have had a number of such reviews along the way and independent expert assessment should have been a continual part of the project.

Other failure points

While the underestimation of complexity, lack of planning, ineffective communications and poor management oversight drove the failure, the project suffered many other difficulties that compounded the problems. Some of those issues were unavoidable, but others were likely a result of the schedule pressure the project was working under. Among the other issues that affected the project;

Risk management failures

The project encountered a number of major technical problems for which no allowances had been made. One of the most significant was caused by the fact that the electrical system suffered from power fluctuations that crashed the system. The resolution to the problem required filters to be built into the electrical power system to eliminate surges. Delivery and installation of the filters took several months, during which time testing was severely constrained.

Such issues were likely predictable had the team focused on risk management activities. Again possibly as a result of the schedule pressure under which they were working, appropriate risk management strategies appear not to have been developed.

Leadership Change

In October of 1992 Walter Slinger died. Singer was the system's de facto sponsor and his death left the project without much needed leadership. According to reports, Mr Slinger's replacement lacked the in-depth engineering knowledge required to understand the system. In addition the replacement manager retained their prior responsibilities and hence was stretched to the limit.

Architectural and design issues

A number of reports indicate that the design the team chose to use was particularly complex and error prone. Among the issues noted;

1. The system had more than 100 individual PCs that were networked together. Failure of any one of the PCs could result in an outage as there was no automatic backup for failed components,
2. The distributed nature of the design (with PCs dotted around the different concourses) added to the difficulty of resolving problems when they arose,
3. The system was unable to detect jams and as a result when a jam occurred, the system simply kept piling up more and more bags making the jam that much worse.

Again schedule pressure may well have been a factor in the design problems. When under excessive schedule pressure teams often settle for the first design they think of. In addition schedule pressure often forces teams to focus on the "happy path" design while spending little time thinking through how to deal with problems and how to make the system fault tolerant.

Conclusion

The Denver debacle is a template for failure that many other projects have followed. As with so many other failures, Denver suffered from;

1. The underestimation of complexity
2. A lack of planning resulting in subsequent changes in strategy
3. Excessive schedule pressure
4. Lack of due diligence
5. Making firm commitments in the face of massive risks and uncertainty
6. Poor stakeholder management
7. Communications breakdowns
8. People working in silos
9. Poor design
10. Failure to perform risk management
11. Failure to understand the implication change requests might have
12. Lack of management oversight

While the above points represent contributors to the failure, there is one central problem that triggered the fiasco. Successful projects are projects in which people make effective decisions and making effective decisions requires a number of ingredients. Chief among those ingredients are knowledge and expertise. Walter Slinger, the airport's Project Management team and even the BAE's Senior Managers did not have prior experience of a system of this scale. In addition, given that automated baggage systems were relatively new, even BAE's Senior Management team only had a limited understanding of what was involved. That lack of knowledge, combined with the fact that expert advice was routinely ignored, is the epicentre of the failure.

The initial planning decisions, the decision to proceed with one airport wide integrated system (despite the fact that it was too late to do so) and the firm contractual commitments to scope, schedule and budget all represented decisions that were made by people who lacked the necessary knowledge. The misjudgements resulting from those decisions were the sparks that ignited the fire.

We are often faced with situations in which we lack the prior experience to know how to proceed with certainty. The way in which we respond to those situations can spell the difference between success and failure. The first step lies in recognizing the situation and Slinger, The Project Management team and BAE's Senior Manager seem to have fallen at that first hurdle. Had they recognized their lack of knowledge and the uncertainty they were facing, they could have taken a number of steps that would have reduced the risk. Chief among those steps would have been listening to those who did have the necessary prior knowledge.

The bright side of the story is that in Feb 1995 DIA did eventually open and despite using a largely manual trolley based system the airport proved to be an operational success [10]. Fears that a manual system would be too slow to service an airport the size of DIA proved to be unfounded.

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