Factors Influencing Time and Cost Overruns in Aircraft Projects

All recent major civil as well as military aircraft projects – A380, B787, A400M – have suffered from massive cost overruns and substantial entry-in-service delays of at least two years. In our paper, we intend to overview the press coverage of the aircraft programs of Boeing's new long-haul wide-body model, the 787 Dreamliner, and the military transport aircraft A400M, designed by European manufacturer Airbus. Using causal mapping, based on a content analysis, we summarize the project events reported in the press that triggered off the chains of causality, which inevitably led to cost overruns and time delays.

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Photo 1: *Airbus Military's A400M airlifter at Farnborough, photo courtesy of Airbus*

A400M: Program Background

Several European national air forces started looking for replacements for their aging military airlift fleets in the early 1980s. The C-160 Transalls as well as the Lockheed C-130 Hercules ought to have been replaced by the Future International Military Airlifter (FIMA) – later renamed into Future Large Aircraft (FLA) - by the late 1990s. But this program was weakened by the opt-out of the US Department of Defense, respectively Lockheed, which had initially been a program partner, and the British government, respectively BAe, which rejoined the project later. Further, the German government temporarily supported the Russian-Ukrainian Antonov 70. However, the final procurement contract, which was signed by seven European NATO members - France, Spain, Turkey, Belgium, Luxembourg, Germany and the UK - and the joint European armaments agency OCCAR, finally launched the A400M program on 27 May 2003. This contract included the delivery of 180 A400M. Italy and Portugal, which had initially ordered 16 and 9 aircraft respectively, later withdrew from the program (see Norris, 2004; Gros-Verheyde, 2009). Presently, the overall program contains only 170 aircraft, because Germany and the UK decided to cancel seven and three ordered aircraft respectively.

The A400M's maiden flight, which initially was scheduled to take place in early 2008, finally occurred on 11 December 2009. According to the procurement contract signed in 2003, the French air force as the launch operator would have received its first aircraft in October 2009. But under the current plan, the first A400M will be handed over to the French air force in late 2012 or early 2013. Germany, the major contractor, will receive its first aircraft, whose delivery was originally planned for November 2010, in 2014 at the earliest.

The costs of the A400M-program have been steadily increasing during the past years. The fixed-price contract of 2003 stipulated a budget of €20.33 billion for the development and production of 180 A400M aircraft. Currently, the program is plagued by a cost overrun of €11.3 billion. Hence, the total development and production costs of the A400M amount to more than €30 billion.

Boeing 787 Dreamliner: Program Background

After cancelling the "Sonic Cruiser" concept, Boeing officially launched the 7E7 program, later renamed into 787 Dreamliner, on 26 April 2004 with an All Nippon Airways (ANA) order for 50 aircraft. The first flight was expected to take place mid-2007 and the deliveries to ANA were scheduled to begin by mid-2008. First rumors about schedule overruns emerged in January 2007 but were dismissed by Boeing. But after the Dreamliner's successful rollout on 8 July 2007, Boeing pushed back the first flight to November/December 2007. The delivery target, however, remained unchanged. In an official press release, Boeing blamed out-of-sequence production work, parts shortages and software and systems integration activities for the delay. Only a short time later, however, in October 2007, Boeing presented a revised program schedule. The first flight was now anticipated

Photo 2: *Boeing 787-8 Dreamliner at Everett - Snohomish County / Paine Field, Washington, USA, photo courtesy of Royal S. King (Airliners.net)*

for March 2008, while the first deliveries were rescheduled to begin late November or December 2008. This time, Boeing cited unspecified assembly challenges as a reason for the delay. However, the updated schedule rapidly turned out to be unrealistic as well and Boeing pushed back the first flight and the delivery plans three times during 2008, postponing the first take-off and the initial deliveries to the second quarter 2009 and first quarter 2010 respectively. According to Boeing, the schedule changes resulted from undone work that travelled from supplier facilities into Boeing's final assembly line and unforeseen rework, e.g. the need to replace thousands of fasteners. Further, a worker's strike at Boeing's facilities impacted the schedule negatively. The last delay in the 787 program was announced in June 2009. Due to a need to reinforce an area within the side-of-body section of the aircraft, the B787's first flight was postponed to the end of 2009, while the first deliveries were projected to occur in the fourth quarter of 2010. The B787 finally completed its maiden flight on 15 December 2009. The launch costumer ANA was supposed to get its first aircraft in the fourth quarter 2010. But after another revision in August 2010, Boeing now expects the delivery of the first Dreamliner in the middle of the first quarter of 2011.

Cause Mapping

Cause mapping works as a useful instrument to structure and analyze complex problems. This tool has initially been developed to explore and graph a person's thinking about a problem or issue. For that reason, cause mapping is also known as cognitive mapping. However, the mapping process and the structure of the map are equal (see Eden, 2004). Thus, we do not differentiate between the two terms, which we will use synonymously.

A Cause map as the result of this modeling process basically consists of two types of elements: concepts and causal beliefs. Concepts pictured as short pieces of text are linked together by arrows representing the causal assertions. The direction of the arrow indicates the direction of the causal relationship. A concept at the tail of an arrow is seen to cause the concept at the arrowhead. Causal linkages can be both negative and positive. A positive relationship between two concepts means that the changes in both concepts are headed in the same direction. For example, an increase in the cause concept at the tail of an arrow leads to an increase in the effect concept at the arrowhead. A negative relationship in turn implies that an increase in the cause variable decreases the corresponding effect concept. A plus sign attached to the linking arrow indicates a positive causality, while a minus sign means a negative relationship. Sometimes an effect variable of one causal relationship is the cause of another effect variable. So, several stated beliefs can be queued to a single causal path (see Axelrod, 1976b; Eden/Ackermann/Cropper, 1992; Fuglseth/Grønhaug, 2002; Eden, 2004).

Causal mapping has some advantages over a non-graphical verbal presentation of (believed) causal relationships. First, because of its simple structure, a cause map provides a vivid overview of causal relations. Second, it visibly links single causal statements together to a whole network of relationships. In doing so, causal maps reveal causal relations which do not have to be clearly stated in the underlying text. Cause mapping somehow means reading between the lines and unveils information that would not have been explored by simply reading the text (see Laukkanen, 1990).

But this technique also has its limitations. For example, causal relations that only occur temporarily or normative conceptions, i.e. what should be done, can hardly be pictured within a cause map (see Laukkanen, 1990). Further, in case of a limited number of cause-effect-relations, it has to be questioned if these relations always have to be transferred into a graphical cause map. The causal relations shown in a small causal map with only a few stated concepts and arrows are sometimes better described through words. The analysis of simple and quite obvious causal relationships does not necessarily require the development of a sophisticated cause map (see Eden, 2004).

Cause maps can be derived from interview recordings or questionnaires. Moreover, cause maps can also result from a content analysis of already existing documents. The advantage of deriving a map from existing documents emerges from the fact that assertions of causal linkages that a person once has mentioned can be rebuilt over and over again. Further, the process of deriving a map from existing documents can be repeated and carried out by different researchers without any loss of information or without widely diverging findings. So, by using content analysis to research available documents a high reliability and validity can be achieved (see Axelrod, 1976a). The disadvantage of analyzing existing documents is that they were made for other purposes than the specific research interest and therefore they may not provide an elaborate data set for answering the research question (see Fuglseth/Grønhaug, 2002).

Cause Map Construction

In our approach, we adopt the method of content analysis because it is a well-elaborated and approved technique for the study of written documents. Content analysis is a research technique for the systematic collection of communication, the objective and quantitative description of its information or content and the making of interferences from the message to its sender, receiver and historical, political and social context (see Krippendorff, 2004).

For the coding of the texts, we follow the guideline of derivation of cause maps from documents prepared by Deegan (2009) and Wrightson (1976). The coding process contains of the following steps:
First of all, the units of interest have to be defined. We analyzed all articles published in the weekly aviation news magazine "Flight International" that deal with delays and cost overruns in the A400M project and the Dreamliner program respectively. Regarding the A400M, our analysis is limited to articles being published between 1 May 2003 and 31 December 2009. This period has been selected because the program was officially launched on 27 May 2003 and the A400M maiden flight took place on 11 December 2009. In the B787 case study, all articles published between April 2004 and December 2009 were researched because – having been launched on 26 April 2004 – the Dreamliner took off for the first time on 15 December 2009 (sampling unit and recording unit). We primarily identified and coded all causal relations in respective texts (content unit).

The coding process starts with the identification of causal relationships in the text. As mentioned above, statements of causal relationship always contain a cause variable, an effect variable and a explicit or implicit "if/then" causal link (cause variable/linkage/effect variable). Whenever possible, the causal statements in the text are quoted directly. Particularly the implicit relationships require the full attention of the coder.

Having found all cause variables, linkages and effects variables, synonymous chains of causality are grouped together because equal variables and linkages later displayed in a cause map render the map larger and more confusing without adding valuable information.

Finally, the identified statements and causal relationships are graphed in a cause map. This means, all cause and effect variables are connected by arrows indicating a causal relationship. A plus or minus signs attached to the arrows inform about the specific type of linkage. Plus (+) means affects positively/leads to/causes and minus (-) stands for affects negatively/does not lead to/hampers.

In our 787 Dreamliner case study, we found 13 articles dealing with the program's shortcomings. Interestingly, all of the articles focused solely on the delays that have occurred in the 787 Dreamliner program. The higher than expected costs in this program were not discussed at all. All articles were published between October 2007 and October 2009 and contained 70 causal relationships. The Flight International coverage of the 787 Dreamliner program delays was dominated by the fastener problem (17 causal relationships). Due to a lack of fasteners, Boeing's suppliers, first of all Italy's Alenia Aeronautica, installed temporary fasteners, which had to be replaced at Boeing's final assembly plant. A large number of fasteners, which had been improperly installed at Alenia's production site, had to be removed by Boeing too. Seven causal relationships dealt with the structural shortcomings in the body-wing join, which were discovered on Boeing's final assembly line. As a consequence, the wing/body attachment structure had to be reinforced, which further delayed the final assembly. Further Flight International articles addressed the difficulties in the fuselage barrels production at Alenia Aeronautica plants. The fuselage barrels, which were shipped to Boeing for final assembly, did not fit smoothly together. Moreover, the barrel's carbon composite skin wrinkled up in the production process. In both cases, the fuselage barrels had to be reworked on Boeing's final assembly line (seven causal relationships). Besides these production issues, the final assembly of the 787 Dreamliner was hampered by a two-month lasting workers' strike at Boeing's facilities (four causal relationships). In conclusion, the Flight International reporting of the 787 Dreamliner program focused on travelled work (five stated causal relationships) due to part shortages and the poor quality of workmanship as well as the impacts of the worker's strike. Further delaying factors reported in Flight International were the problems in the development of the flight-control software and the need to redesign the center wing box after potential for premature buckling in the spars had been found during static tests. All the reported causes of the delay were previously stated in official documents of Boeing.

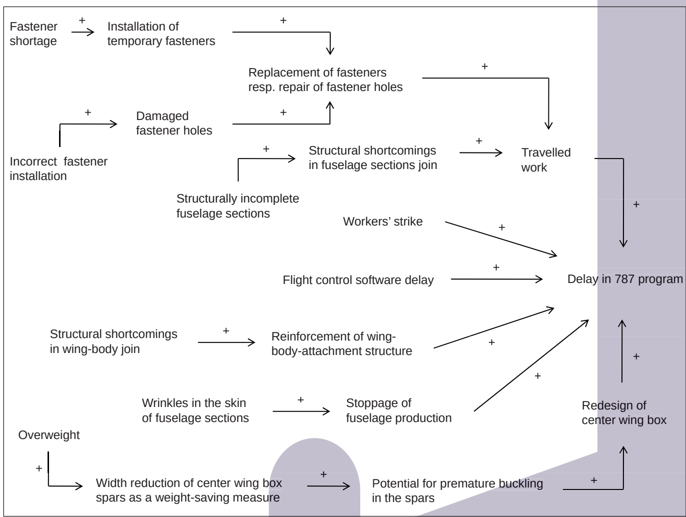

Figure 1: *Cause Map of the Boeing 787 Dreamliner program delay*

Regarding budget overruns and delays in the A400M program, we identified 21 articles and 50 causal linkages. All articles were published between May 2003 and September 2009. Two main triggers for the repeated postponements of the initial flight were discussed in Flight International. First and foremost, the unavailability of the propulsion system had severe impacts on the program schedule. Due to a series of delays in the development and testing of the EPI Europrop International made TP400-D6 turboprop engine, Airbus had repeatedly been forced to slip the first flight of the A400M (26 causal relationships). The first delay in the engine program became apparent in mid-2005 when higher than expected loads had emerged during testing, which resulted in the need for a redesign of the engine. Further, the power plant suffered from troubles with the oil system, the gear box, the torque sensor and with the engine control software. The first engine was scheduled to go to ground tests in August 2005 and to fly for the first time in September 2007. The ground tests started nearly on time in October 2005, but the engine's maiden flight took place not before December 2008. However, a second bunch of triggers cluster around the delays to final-assembly activities, which were predominantly caused by unspecified additional systems development difficulties and a relocation of the final assembly plant (ten causal relationships).

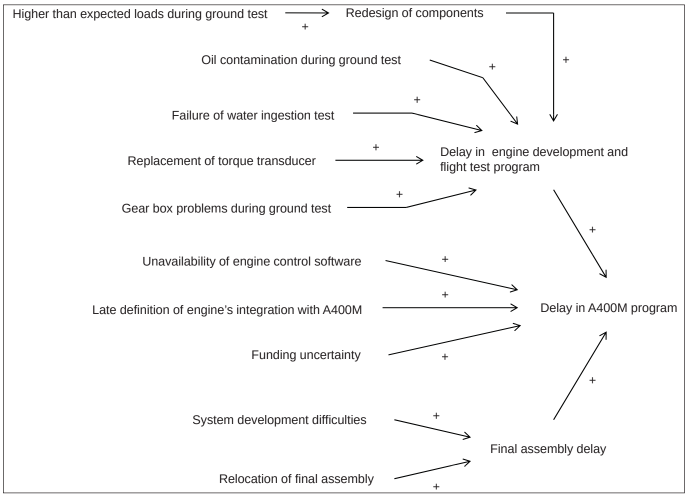

Figure 2: *Cause Map of the Airbus A400M program delay*

In official documents, e.g. press releases and annual reports, Airbus states that the slow progress in engine and system development, in particular the unavailability of the engine control software, and a flight test program that differs significantly from that of commercial Airbus aircraft caused the delays in the A400M program.

Conclusions

In our paper, we explored the press coverage of two major aircraft projects that both suffered from cost overruns and schedule delays. Using content analyses and causal mapping, we identified triggers which were blamed for cost overruns and time delays in the aircraft programs of Boeing's B787 Dreamliner and the military transport aircraft A400M designed by the European manufacturer Airbus.

In our B787 Dreamliner case study, we found that constructional faults as well as managerial diseases, which both caused severe program delays, dominated the press coverage. In the A400M program, the predominant delaying factors were constructional shortcomings, too. We conclude that all causes of delay which were presented in Flight International had previously been published in official documents of the aircraft manufacturers.

This opens a broad agenda for future research. First, very little empirical work has been done to demonstrate the benefit of content analyses for causal mapping and system dynamics so far. Second, it would be worthwhile to research the underlying database more intensely. Several other entry-in-service delays and cost overruns remain as yet unexplored and unexplained. If researchers as well as managers had a deeper insight into the process of developing aircraft, the bundle of causal linkages could be disclosed more easily and strategies to avoid time delays and cost overruns could be developed.

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Photo 3: *Airbus A400M in production, photo courtesy of Airbus*

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