Controller-Pilot Data Link Communication – (TAXI-CPDLC)

Jakobi, Joern
DLR
joern.jakobi@dlr.de

Increasing traffic rates in aviation cause bottlenecks in safety and efficiency, particularly on the ground at major airports. Voice communication radio channel are often overloaded and pilots are less supported to find their way and to avoid other traffic. Controller-Pilot Data Link Communication during taxi (TAXI-CPDLC) is one promising service to bring benefits in terms of unload the radio channel by taking over 'routine communication' and to enable the transfer and representation of the cleared taxi route in the cockpit. This paper details the concept and results of a new TAXI-CPDLC service and provides recommendations for its future use and implementation.

1. Introduction

Today pilots survey the surrounding ground traffic by looking out of the window only supported by the Tower controller's information via radio. They use airport paper charts to find their way that was cleared by the controller via voice communication. There are nearly no onboard assistant systems supporting them to find their way and to avoid collisions. Particularly in low visibility and with dense traffic, navigation and collision avoidance becomes complicated and safety critical.

To overcome these issues new concepts for communication between controller and pilot were considered in the aviation research community. Developing such a new concept, which includes new procedures and operational requirements [EMMA2, 2008a], workshops with controllers and pilots, as well as representatives of the aviation industry and researchers were held. Field trials at Airport Prague Ruzyne supported by the use of test aircraft and test vehicles, as well as tower and cockpit real time simulation experiments were performed to evaluate this concept.

This paper details the description of the TAXI-CPDLC concept, the validation methodology, results and conclusions. Since the concept and the developed prototypes were in an early stage of development, the focus was laid on proving technical and operational feasibility.

2. TAXI-CPDLC Service Descriptions

Prerequisite for TAXI-CPDLC is that an optimal taxi route is proposed for each aircraft by an automatic routing function. This taxi route is provided to the controller through electronic flight strips (EFS). By clicking on the individual EFS, the controller can quickly update, validate and assign the taxi route to a flight and pass it to the to the cockpit crew by TAXI-CPDLC. Similarly, other instructions, such as 'start-up' and 'pushback', could be transmitted by data link and also acknowledged by the pilot by data link. This could save valuable time on frequency and help avoid misunderstandings by ensuring more on-board transparency.

The main operationally significant aspects that were shaped by controllers and pilots are outlined in the following paragraphs:

- The implementation of TAXI-CPDLC in a Tower environment requires the availability of an EFS display and an automatic routing function, which release the controller as far as possible from the manual composition of messages.
- Since a complete data link communication loop (request – clearance – acknowledgement) will usually take more time than radio, non time-critical information and clearances seemed to be the most promising aspects to be performed by data link. Focus is laid on 'start-up', 'push-back', 'taxi clearance,' and 'handover' instructions.
- When the aircraft is ready for start-up, push-back or taxiing out, the pilot not-flying sends a request by data link to the controller, which pops up in the related EFS. With a taxi request a proposed taxi route is already displayed in the EFS and the controller validates and clears the computed taxi route by a click on the clearance button.
  Note: Independently of having received a request from the flight crew or not, the controller is always able to deliver a clearance.

- The flight crew verifies the operational contents of the clearance and the pilot not-flying (PNF) transmits a response message via data link (usually a 'WILCO' response). This response closes the data link communication loop.
- The complete taxi route (including intermediate and final holding points) is generated by a routing function, knowing the starting point and end point of the route. The complete taxi route may include clearance elements (e.g. TAXI TO …), information elements (e.g. EXPECT ROUTING TO… VIA …), clearance limits (HOLD SHORT OF …), and 'free text' if needed.
- Whenever the expected taxi route or the already cleared taxi route is no longer valid, a taxi route revision is needed and a REVISE TAXI message is sent to the flight deck. The revision of a taxi route can be requested by the flight crew or initiated by the controller.
  Note: Communication with a taxiing aircraft is time- and safety critical. Controllers in the experiments were told that for taxi revisions they can decide the communication medium, data link or voice.
- When an operational exception (e.g. UNABLE response) or a safety-critical event (e.g. conflicting taxiing traffic) occurs, which requires immediate action, reversals, or the provision of additional information, the immediate use of voice was recommended.
- When a controller or pilot communicates via voice, the response should be via voice.
- TAXI-CPDLC can be carried out in conjunction with the transfer of voice communication.
- Each data link message transmission is followed by a logical acknowledgement (LACK). In other words, the sender gets an immediate feedback that the message has been transmitted completely and is available on the recipient's display.
- Handover instructions are given by data link transmission: 'CONTACT [unit name] [frequency]' informing the flight crew about the radio frequency of the next control position. However, the initial call with the next control position should be performed by voice in order to guarantee that the radiotelephony (R/T) contact has been established.

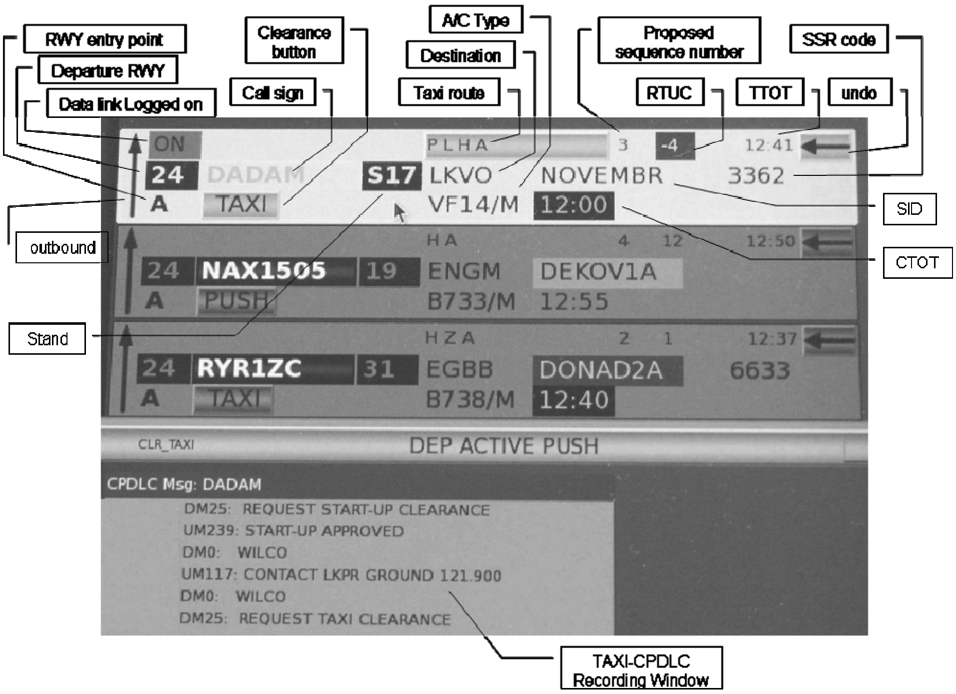
3. Methodology

The objective of the evaluation was to assess the potential operational impact of the proposed concept and to explore its performance in terms of compliance with the requirements of the relevant stakeholders. The E-OCVM (European Operational Concept Validation Methodology) [EC & EUROCONTROL, 2008] maturity model defines different stages of concept maturity in the concept validation life cycle, ranging from the V0 "initial idea" to V5 "implemented concept" (see figure 1).

The new TAXI-CPDLC service provided a concept maturity level of V1-V2. Thus, the feedback gathered was mainly regarding their operational feasibility in terms of proving the new procedures and verifying the operational requirements. This was done by a debriefing questionnaire addressing all those feasibility criteria.

3.1 Validation Platforms

For the real-time simulation (RTS) exercises the DLR Apron and Tower Simulator (ATS) and the generic experimental cockpit simulator (GECO) were used. The ATS at DLR-Braunschweig is an ATC real-time simulation facility for human-in-the-loop simulation with a 300° outside view. It was configured to accurately simulate the PRG control tower environment. Pseudo-pilots in a separate room piloted the simulated aircraft and communicated with the controllers via a radio transmission line or data link. In addition, the GECO was manned by commercial pilots and was included in the traffic scenarios as single aircraft. In the experimental conditions, controllers were provided with an EFS display that allowed them to operate routing and TAXI-CPDLC (see figure 1).



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CPDLC Msg: DADAM
DM25:  REQUEST START-UP CLEARANCE
UM239: START-UP APPROVED
DM0:   WILCO
UM117: CONTACT LKPR GROUND 121.900
DM0:   WILCO
DM25:  REQUEST TAXI CLEARANCE
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Figure 1: EFS Screenshot showing EFS for three outbound flights[1] [2] [3]

3.2 Experimental setting

There were two groups of three controllers each (N=6) from the Czech air traffic service provider ANS CR. All six were male and work at the control tower at PRG. The three controllers of each group were allocated to three CWPs tower executive controller (TEC), ground executive controller (GEC), clearance delivery controller (CDC). In the cockpit simulator eight commercial pilots took part in the simulation trial by forming four crews, whereas PF and PNF positions were alternated. In total they performed 15 test runs whereas each lasted 30 minutes. Two traffic scenarios were used, one with departures and landings on runway 24 the other on runway 06, in order to be able to investigate different taxi-out and taxi-in conditions.

4. Results

After all trials the debriefing questionnaire was given to all controllers. The items asked if operational requirements were fulfilled and procedures could be accepted. All items were to be answered by a six-point Likert scale with answers from 1 (disagreement) through 6 (agreement). Each QE-OF item was tested for its statistical significance by a single sample size binominal test as a non-parametric by a test ratio of p = 0.5, an expected mean value of 3.5 and α = 0.05. (see table 1).

Table 1: TAXI-CPDLC related questions to operational feasibility (QE-OF)

ID	Questions / Statements	M	N	SD	p[4]
35-H	I was reliably presented with a means to operate clearances via the electronic flight strips.	5.17	6	0.75	.03*
43-H	I was reliably informed if an aircraft was datalink equipped or not.	5.33	6	0.52	.03*
2-T	When needed, it was always possible to switch back from data link communication to direct pilot-controller voice communications in a safe and efficient manner.	5.50	6	0.55	.03*
3-T	I was provided with an effective human-machine interface to permit data link efficient communication with the pilots.	4.50	6	0.55	.03*
4-T	I was provided with an effective human-machine interface to permit efficient data link communication with other controllers.	4.17	6	0.41	.03*
7-T	Messages were delivered in the order that they are sent.	4.4	5	0.5	.05

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[1] .Information in the EFSs is also color-coded, but due to the black/white picture not visible here.

[2] .EFS dealing with DMAN, TAXI-CPDLC, and routing information was provided by Northrop Grumman Park Air Systems, the DMAN by DLR, ATN radio by SELEX Communication, and ATN stack and router by Airtel.

[3] .The picture is shown by courtesy of Northrop Grumman Park Air Systems

[4] .A star (*) attached to the p-value indicates significance ($p \leq .05$).

ID	Questions / Statements	M	N	SD	p[4]
		0		5	*
8-T	I was always provided with the capability to respond to messages, to issue clearances, instructions and advisories, and to request and provide information, as appropriate.	4.67	6	0.52	.03*
11-T	Aircraft were always under the control of only one ATC unit at a time.	5.43	7	0.53	.02*
13-T	Each data link message transmission was followed by a positive technical acknowledgement, which informed me that the message has completely been transmitted and is available on the recipient's display.	4.50	6	0.84	.22
14-T	The time I need to spend to monitor the traffic situation on the TSD or by looking outside was not impaired by operating TAXI-CPDLC.	4.50	6	0.84	.03*
15-T	Input requests by keyboard or mouse to operate TAXI-CPDLC were reasonably low.	5.17	6	0.41	.03*
16-T	The total time required for selecting a TAXI-CPDLC message, transmission of the message, or reading and interpretation of a received message was adequate to communicate in a safe and efficient manner.	4.50	6	0.84	.22
17-T	The pilot's TAXI-CPDLC response time was quick enough to work in a safe and efficient manner.	4.80	5	0.45	.05*
18-T	The mix of TAXI-CPDLC or voice handled aircraft did not lead to additional workload or communication errors.	4.50	6	0.55	.03*
19-T	The mix of TAXI-CPDLC and voice communication for different phases of a single flight did not lead to confusion and safety critical communication errors.	5.00	6	0.00	.03*
20-T	The automatic generation of the taxi route for a flight handled by TAXI-CPDLC was appropriate and met my demands.	3.50	6	1.05	1.0
21-T	If the automatic generation of the taxi route failed or did not meet my expectation I could easily select or compose an adequate taxi route manually.	3.20	5	1.30	1.0
22-T	The TAXI-CPDLC requests or clearances were easy to understand and could be handled in a safe and efficient way.	4.80	5	0.84	.05*
23-T	It was easy to recognize an incoming data link message or request.	3.83	6	0.75	.69
24-T	I never sent unintentionally a TAXI-CPDLC message to a wrong aircraft.	5.17	6	0.75	.03*
25-T	Sending taxi route information to the cockpit in advance of the real taxi route clearance is an appropriate procedure to provide an enhanced service to the flight crews.	5.00	6	0.63	.03*
27-T	TAXI-CPDLC communication while the aircraft was taxiing could be performed in a safe and efficient way.	4.40	5	0.55	.05*
28-T	The frequency of the next control position can be transmitted silently by a TAXI-CPDLC massage, but the initial call from the pilot at the next control position should be retained by voice.	5.17	6	0.98	.03*

18 of the 23 items were answered significantly positive: All requirements were verified, all procedures were accepted and previous stated anticipated concerns could be rejected. The five less positively answered items refer mainly to the flexibility of the taxi route and the missing of a sound for an incoming message.

By a descriptive analysis comparing the times needed for R/T communication in a test run with and without use of TAXI-CPDLC was performed for the ground ATCO position (GEC).

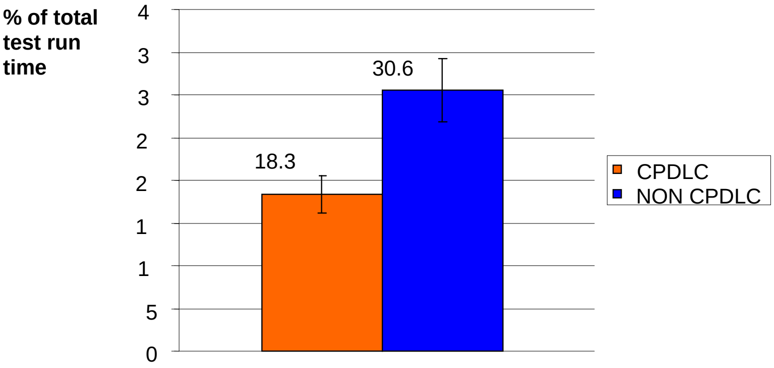

Figure 2: Percentage of time needed for R/T Communication with and without TAXI-CPDLC

The bar chart in figure 2 depicts the different amounts: In 15 test runs the voice communication supported by TAXI-CPDLC could be reduced from 30.6% to 18.3% of the total amount of time.

Furthermore, the most meaningful controller comments regarding TAXI-CPDLC are reported below. The comments reflect a common opinion of all six controllers.

- *A transmission failure, instead of a positive LACK each time, should be transmitted.*
- *An acoustic signal for incoming TAXI-CPLDC could be helpful to attract attention to an incoming message.*
- *The following phraseology was preferred for the initial call:*
    - *Pilot: "Ruzyně Ground, DLH621 on your frequency"*
    - *ATC: "DLH621 follow data link"*
    - *Pilot: "Following data link, DLH621"*
- *A "PUSHBACK APPROVAL" message does not have to be extended by additional data link messages for special pushback procedures. If this would be needed voice communication can be used.*
- *Dealing with a revised taxi route while taxiing via data link was seen as potentially feasible by the controllers. When sending the new taxi route a REVISED message was linked to the taxi route. This was appreciated.*
- *Landing, go-around, line-up and take-off should be cleared by voice, as previously agreed.*
- *A data link runway crossing clearance would have the potential to solve the operational problem to switch off the red stop bar on the EMM, the clearance limit of the taxi route that was transmitted to the flight deck.*

5. Discussion

The new service TAXI-CPDLC was investigated in a simulation environment and could prove its operational feasibility. The ground executive controller (GEC) and the clearance delivery dispatcher (CDD) handled START-UP, PUSHBACK, TAXI-in, TAXI-out, and HANDOVER by data link. For instance, with outbound traffic the GEC transmitted the complete taxi-out clearance including the clearance limit, which is usually a runway to be crossed: "TAXI TO RWY 06 HOLDINGPOINT VIA TWY P L F HOLD SHORT OF RWY 13 NEXT EXPECT VIA TWY F". Close to that clearance limit the GEC handed over the flight to the tower executive controller (TEC) by "CONTACT LKPR TOWER 118.100". At this point the TEC continued control by voice communication only since runway related clearances are rather time critical. With GEC and CDD also the readback was done by data link, but pilots as well as GEC and CDD could always revert to voice when they felt a need for. Controllers' feedback for handling clearances by TAXI-CPDLC was predominantly positive. The controllers significantly admitted that they were provided with a rather effective human-machine interface to permit data link communication with the pilots. Furthermore, a mix of TAXI-CPDLC and voice communication for different phases of a single flight and a mix of equipped and non-equipped aircraft did not lead to confusion and safety critical communication errors. Prague controllers rejected the formerly mentioned constraints, that they would be distracted by TAXI-CPDLC from looking outside, and that they would be unsettled by too many input requests to operate TAXI-CPDLC (cf. results in table 1).

6. References

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