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FLIGHT PROGRESS STRIPS IN TOWERS: FREQUENCY INDEX AND PERCEIVED PSYCHOLOGICAL BENEFITS

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A team of subject matter experts (SMEs) observed tower air traffic controllers as they marked flight progress strips (FPSs) at ten facilities. SMEs tallied marks and actions controllers made at various positions during 332 twenty-minute observation periods. During many of the observation periods, one or more marks or actions were targeted for interviews. The benefits controllers perceived from making the targeted mark or action varied across position. The findings from this study will help engineers preserve the functional benefits received from paper FPS when designing electronic FPSs.

Introduction

A flight progress strip (FPS) is often a critical, if not required, tool that aids air traffic controllers in safely managing the movement of thousands of flights daily. Traditionally, an FPS is a paper strip demarcated by sections called blocks that include information about an aircraft such as call sign, type of aircraft, flight level, heading, route of flight, and destination. A controller uses the FPS to update information about a flight, communicate information to other team members, verify a procedure has been executed, and organize information.

A controller accomplishes these tasks by making marks on the FPS or altering the position of the FPS by offsetting or moving it in the strip bay. With the advent of electronic substitutions for paper across industries, it is important to determine the operational as well as the psychological benefits of using paper FPSs.

Substituting electronic FPSs for paper without examining how controllers use paper FPSs may preempt the benefits a controller experiences by using paper. For example, Luff, Heath, and Greatbatch (1992) claimed that paper is superior to electronic substitution for the following five reasons: ease of data entry, flexibility of data entry, option with data input sequences, document differentiation, and mobility. Additionally, Vortac, Edwards, Fuller, and Manning (1993) identified multiple potential cognitive benefits of using paper FPSs in an en route environment.

However, transferring to a paperless environment has benefits. For example, Vortac et al. (1993) showed that prohibiting the use of a writing utensil and preventing the movement of an FPS actually improved prospective memory. In addition, Vortac, Barile, Albright, Truitt, Manning, and Bain (1996) found that en route controllers actually preferred electronic FPSs.

The goal of this study was to explore the operational and psychological benefits of tower controllers' use of paper FPSs. Without this understanding, important considerations may be excluded from the design of electronic replacements (Vortac, Edwards, & Manning, 1994). Although previous studies examined en route controllers (Durso, Batsakes, Crutchfield, Braden, & Manning, 2004; Durso & Manning, 2003; Durso & Manning, 2002), tower controllers and en route controllers may differ in the usage and perceived benefits gained from paper FPSs. Therefore, an important consideration for designing electronic FPSs is to maintain not just the superficial benefits, but also preserve any functional benefits, if any, gained from paper.

Method

Observations and interviews were conducted at ten air traffic control towers across the United States. Data collection occurred at two facilities within a metropolitan area in five different regions of the country. The towers varied in volume of aircraft operations for each respective airport (small, medium, or large), number of runways, and configuration of runways (crossing, parallel, or angular).

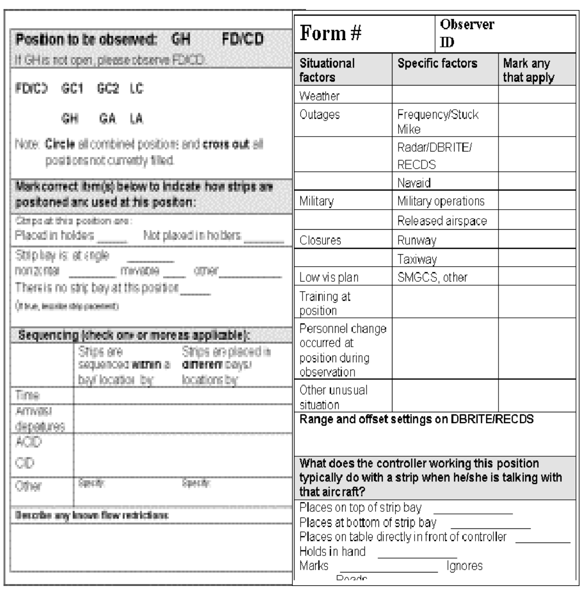
The four subject matter experts (SMEs) who conducted the observations were certified professional controllers (CPCs) who were not bargaining unit members. The SMEs had an average of 24.6 years experience as controllers. Researchers and graduate students of Texas Tech University and the Civil Aerospace Medical Institute (CAMI) conducted interviews. Two SMEs accompanied a group of interviewers to each metropolitan area, and no SME conducted observations at any facility that was in the same Federal Aviation Administration (FAA) region where that SME worked.

Participants

Observations were made of 332 positions across the ten facilities. Observations of 95 controllers who worked the flight data/clearance delivery (FD/CD), ground control (GC), or local control (LC) positions at the time of the observation were invited and agreed to participate in an interview. However, 175 interviews were conducted because several controllers were observed and interviewed on multiple occasions. The average age of controllers interviewed was 43.8 years, with an average of 17.8 years as a CPC, and approximately 10 years working at their respective facility.

Materials

During an orientation and training session prior to the first data collection, the researchers and SMEs developed an observation form. The first part of the observation form recorded situational factors such as current conditions, amount of traffic, and positions active at the time of the observation session (See Figure 1a). The second part of the observation form recorded the most likely actions and events a controller would mark on an FPS (See Figure 1b). The events marked were organized to represent the most logical flow.


Position to be observed: GH FD/CD
If GH is not open, please observe FD/CD.

FD/CD GC1 GC2 LC
GH GA LA

Note: **Circle** all combined positions and **cross out** all positions not currently filled.

Mark correct item(s) below to indicate how strips are positioned and used at this position:
Strips at this position are:
Placed in holders _____ Not placed in holders _______
Strip bay is: at single _______
nonzonal _______ movable ___ other_________
There is no strip bay at this position_____

Sequencing (check one or more as applicable):

	Strips are sequenced **within** a bay/ location by:	Strips are placed in **different** bays/ locations by:
Time		
Arrivals/ departures		
ACID		
CID		
Other	Specify:	Specify:

Describe any known flow restrictions:

Form # | **Observer ID**

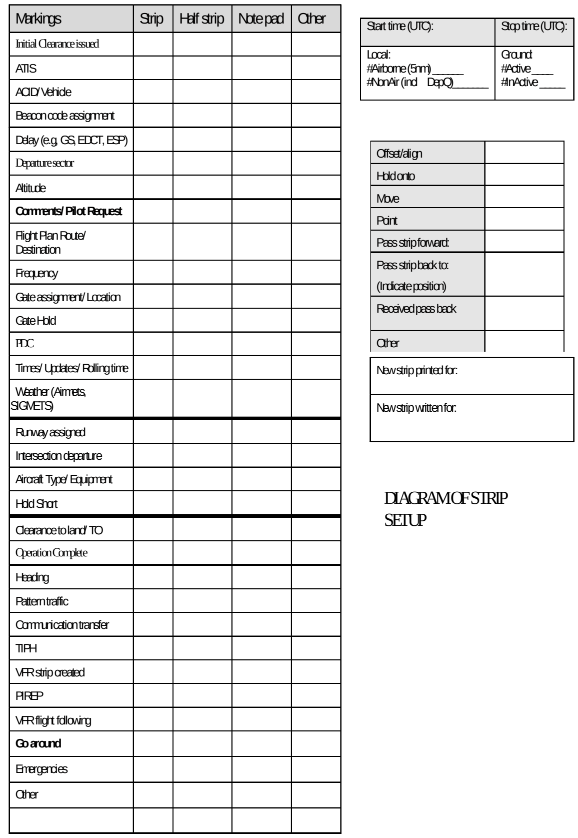
Situational factors	**Specific factors**	**Mark any that apply**
Weather		
Outages	Frequency/Stuck Mike	
	Radar/DBRITE/ RECDS	
	Navaid	
Military	Military operations	
	Released airspace	
Closures	Runway	
	Taxiway	
Low vis plan	SMGCS, other	
Training at position		
Personnel change occurred at position during observation		
Other unusual situation		

Range and offset settings on DBRITE/RECDS

What does the controller working this position typically do with a strip when he/she is talking with that aircraft?
Places on top of strip bay __________
Places at bottom of strip bay __________
Places on table directly in front of controller ________
Holds in hand __________
Marks ______________ Ignores

Figure 1a. *Front side of observation form.*

Columns on the observation form indicated if the controller was using a strip, half strip, or notepad to make the mark. A half strip is a regular strip that has been cut in half when additional information is not needed for that flight. For example, many half strips are used for visual flight rule (VFR) traffic. The observation form also provided a space for SMEs to indicate how the controller handled the strip, including how it was placed in the strip bay and when it was passed to another controller. A notepad is a pad of paper the CPC uses to make notes or marks for flights that do not have an FPS.



Markings	Strip	Half strip	Note pad	Other
Initial Clearance issued				
ATIS				
ACID/ Vehicle				
Beacon code assignment				
Delay (e.g. GS, EDCT, ESP)				
Departure sector				
Altitude				
Comments/ Pilot Request				
Flight Plan Route/ Destination				
Frequency				
Gate assignment/ Location				
Gate Hold				
PDC				
Times/ Updates/ Rolling time				
Weather (Airmets, SIGMETS)				
Runway assigned				
Intersection departure				
Aircraft Type/ Equipment				
Hold Short				
Clearance to land/ TO				
Operation Complete				
Heading				
Pattern traffic				
Communication transfer				
TIPH				
VFR strip created				
PIREP				
VFR flight following				
Go around				
Emergencies				
Other				

Start time (UTC):	Stop time (UTC):
Local: #Airborne (5nm) _____ #NonAir (incl DepQ)______	Ground: #Active ____ #InActive _____

Offset/align	
Hold onto	
Move	
Point	
Pass strip forward:	
Pass strip back to: (Indicate position)	
Received pass back	
Other	

New strip printed for:

New strip written for:

DIAGRAM OF STRIP SETUP

Figure 1b. *Back side of observation form.*

In addition to some basic biographical information, the interview form solicited open-ended questions a) if a targeted mark or action was required by the facility's standard operation procedures (SOP), b) the benefits received from making that mark or action, and c) if and how that mark or action helped achieve a goal. The interview form also consisted of 12 questions with a 7-point Likert scale about how much the targeted mark or action related to five psychological dimensions: communication, memory, workload, situation awareness, and organization.

Procedure

Data were collected over three days at two facilities in a metropolitan area. During two of the days, the SMEs rotated between each facility and for one day, the SMEs paired up at the larger of the two facilities. Thus, data were collected during all three days at the

larger facility and during two days at the smaller facility. Therefore, each SME spent two days collecting data at the larger facility, and one day collecting data at the smaller facility.

Coordination was arranged through FAA headquarters, the regional offices, and individual facility managers to conduct the observations. Controllers were informed of the intent to collect data and had the opportunity to refuse being observed. Some controllers who agreed to be observed were asked to participate in an interview. The facility management agreed to allow the controllers to be interviewed without encroaching on their normal break time.

All positions, including positions that were always open and those that were periodically open, were observed using countered-balanced schedules. Because some positions may not have been open during the observation period, a backup position that was always active, such as FD/CD, GC, or LC, was randomly selected. If the controller at the selected position did not want to be observed, the SME selected the next position in the queue to be observed. This current paper analyzes data collected from the positions of FD/CD, GC, and LC when they were not combined with any other position.

During each observation period, the SME observed the controller at the selected position in an unobtrusive manner. SMEs were not "plugged-in." That is, the SMEs did not listen to the dialogue between controllers and pilots. For each observation, the SME tallied the controller's marks and actions on the standardized observation form. The SME also noted where the controller placed the mark (e.g., strip, half-strip, note pad) and what specific actions the controllers made (e.g., passing the strip to another controller, repositioning the strip). Each SME made twelve 20-minute observations each day. Generally, the SMEs conducted six consecutive observations before taking a one to two-hour break.

For most observations, the SME invited the controller for an interview because he or she made one or more marks or actions during the observation period. The SME handed the controller a receipt and encouraged him or her to talk with one of the interviewers at the controller's earliest convenience. Because the goal of this study was to provide a broad spectrum of how controllers use and benefit from marks and actions, SMEs were given the latitude to decide which marks and/or actions to select for an interview. On some occasions, the SME selected a typical mark or action; on other occasions, the SME selected an unusual mark or action. After an observation session, the SME gave a duplicate copy of the receipt, the observation form, and a copy of the strip or notepad containing the targeted mark or action to the interviewer.

After a controller selected for an interview was relieved from the controller's position, he or she met with an interviewer for approximately 15 minutes. The controller's receipt was matched with the interviewer's receipt to confirm that the controller had made the targeted mark or action that prompted the interview. In the event the controller stated he or she did not make that mark or did not remember the situation, another mark on the form was selected for interview. If several controllers had already been interviewed about the targeted mark or action, the interviewer selected another mark or action. The interviewer and controller then reviewed the targeted mark or action about when and why it was made. The interviewer asked the controller to consider that targeted mark or action when completing the questions on the interview form.

Results

Observation Form

An overall frequency count of marks made from FD/CD, GC, and LC for all facilities showed that "operation complete" was the most frequent type of mark or action made. Figure 2 shows the percentage of marks made by type of mark.

These percentages were broken down by position: FD/CD, GC, and LC. The frequency was the average number of marks per observation period (e.g., 20 minutes). Inspection of Figures 3 (a-c) shows how the frequencies of marks varied across positions. For example, "initial clearance" was rated in the top two types of marks made by FD/CD but at the bottom for LC. Likewise, "clearance to land" was rated as the third most frequent mark made by LC but the least frequent mark made by FD/CD and GC. Inspection of Figures 3(a-c) show FD/CD made more marks than either GC or LC; as expected, more marks were made at the larger facilities than at medium and smaller facilities.

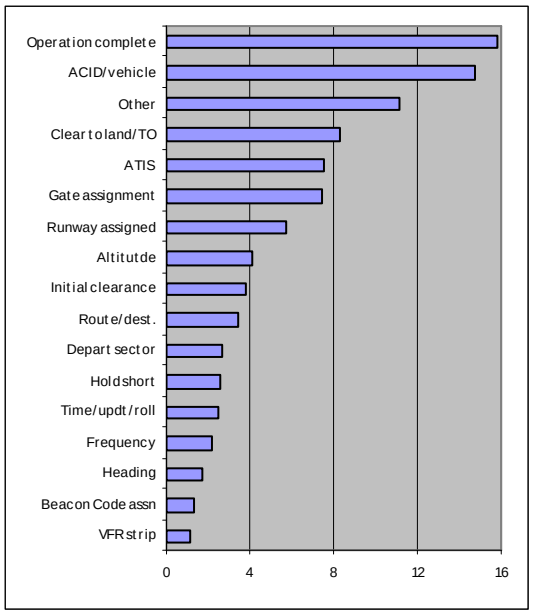


Figure 2. *Percentage of each type of mark made*

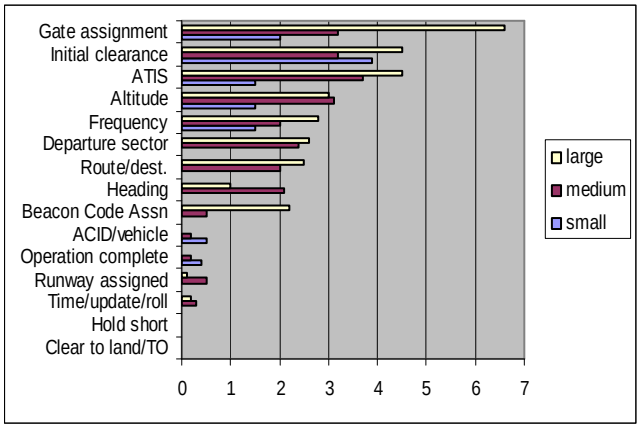


Figure 3a. *Average number of marks per 20-minute period for FD/CD.*

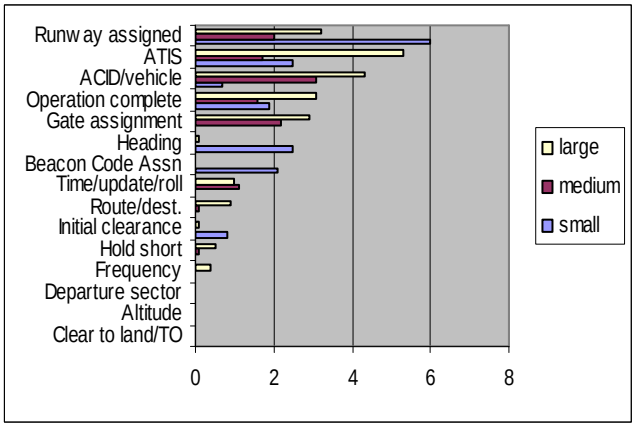


Figure 3b. *Average number of marks per 20-minute period for GC.*

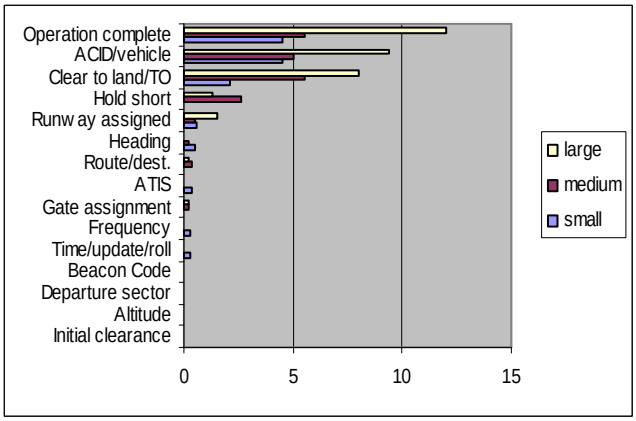


Figure 3c. *Average number of marks per 20-minute period for LC.*

Interview Questions

The first interview question asked the controllers if the targeted mark was required, benefited him or her, or both. Figures 4 (a-c) show the reason marks were made across positions.

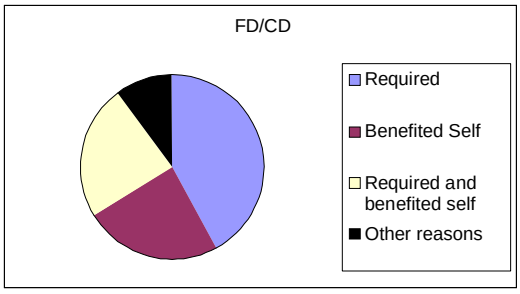


Figure 4a. *Reasons controllers at the FD/CD positions said they made targeted mark or action.*

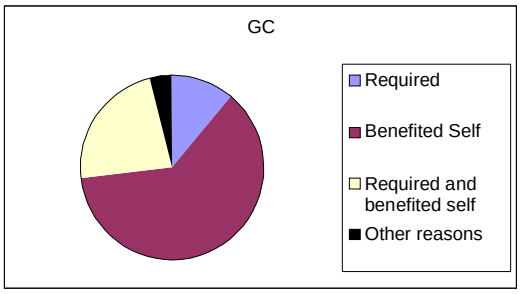


Figure 4b. *Reasons controllers at the GC position said they made targeted mark or action.*

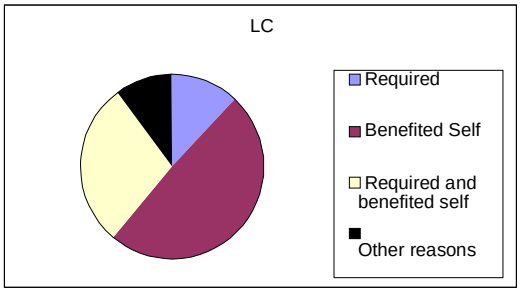


Figure 4c. *Reasons controllers at the LC position said they made targeted mark or action.*

Controllers at the FD/CD position were much more likely to make the targeted mark or action because it was required, rather than because of a perceived benefit to him or her. However, controllers at the GC and LC position were two times more likely to state that they made the mark because it benefited them, rather than because it was required.

The goal the controllers felt the targeted mark or action helped them achieve was scored and categorized as either psychological, operational, or both. An answer that was scored as psychological would be some individual benefit to the controller such as prospective memory or situation awareness. An answer that was scored as operational would be to satisfy a task required in the SOP, such as a count of aircraft or to communicate information to another team member. Figure 5 shows that the benefits for FD/CD were more operational than psychological and about evenly split for GC and LC.

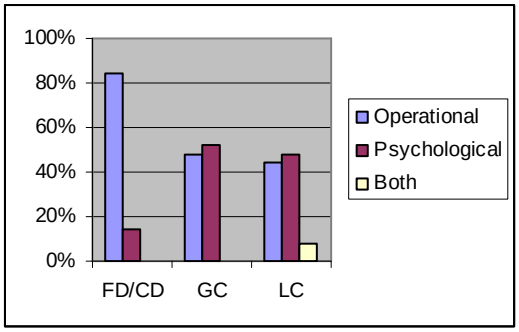


Figure 5. *Goals the marks or actions helped controllers achieve across positions.*

During the interview, controllers who said a targeted mark or action benefited them (rather than simply being required) were asked to specify the benefit. Their answers were scored along five psychological dimensions: communication, memory, organization, situation awareness, and workload. Figure 6 shows that the marks or actions made by FD/CD were most beneficial as an aid to communications and memory. GC made the marks as an aid to memory, situation awareness, and workload; LC made the marks and actions as an aid to memory and situation awareness.

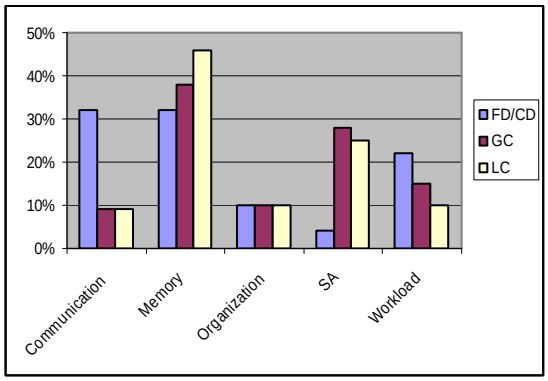


Figure 6. *Psychological benefits received form making targeted marks and action across position.*

For the final part of the interview, controllers used a 7-point Likert scale to answer questions about how well they felt the targeted mark or action related to each question. Each question was designed to elicit one of the five psychological dimensions. Table 1 shows mean ratings for controllers at all positions and separately by each position described above.

Psychological Dimension	Total Mean (SD)	FD/CD Mean (SD)	GC Mean (SD)	LC Mean (SD)
Communication	4.81 (2.27)	5.95 (1.67)	4.99 (2.13)	3.29 (2.16)
Memory	5.23 (1.90)	4.66 (1.91)	5.43 (2.07)	5.80 (1.62)
Organization	5.06 (1.75)	4.44 (1.81)	5.41 (1.85)	5.52 (1.59)
Situation Awareness	4.80 (1.86)	4.03 (1.90)	5.21 (1.85)	5.35 (1.59)
Workload	5.20 (1.74)	5.93 (1.44)	5.58 (1.54)	4.37 (1.91)

Table 1. *Ratings on 7-point Likert scale of psychological dimensions across position.*

Discussion

Some of the findings from these data are not surprising. For example, controllers at larger facilities made more marks than at smaller facilities, and certain marks were more specific to position. However, the benefits the controller gained from the marks varied by position.

Although controllers working the FD/CD position made more marks than did controllers working GC or LC, their marks overwhelmingly were made for operational reasons. The primary benefits of marks

made by FD/CD were for communication. The FD/CD position updates the flight plan printed on the FPS, coordinates flight plan information with pilots, and starts the flow among the other team members. FD/CD does not direct the activities of surface or air movement. Rather, the primary responsibility of FD/CD is to ensure the flight plan is accurate and make sure this information is communicated between the flight crew and other CPC positions. Thus, other than communication and some workload benefits, strip marking seems to have few other benefits for the FD/CD position.

GC and LC experienced greater psychological benefits than FD/CD. The GC position is responsible for movement of aircraft and vehicles on the surface (e.g., taxiways). The LC position controls aircraft on active runways and during take offs and landings. The benefits most often perceived by GC were memory, workload, and situation awareness. The benefits most often perceived by LC were memory and situation awareness.

Additional analyses are being conducted using these data. Controllers' perceived benefits are being compared with importance ratings. The SMEs and a group of controllers not participating in this study independently rated the marks based on their perceived importance.

Before designing an electronic FPS, the perceived benefits found in this study need to be explored as actual benefits to the controller. Future studies will examine information requirements associated with paper FPSs and how they might be incorporated into electronic FPSs.

Acknowledgements

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