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USER REQUEST EVALUATION TOOL (URET) ADOPTION AND ADAPTATION, THREE CENTER CASE STUDY

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Abstract

The objective of this paper is to present findings of exploratory interviews regarding the air traffic controllers' adoption and adaptation of User Request Evaluation Tool (URET). The importance of this investigation lies in better understanding of changes brought about by the use of decision support tools by sector controller teams and what can be done to avoid some of the unintended consequences.

The main purpose of URET is to support sector team strategic planning allowing controllers to concentrate on more user-beneficial control actions. Actual improvements depend on the way controllers use the automation tools in their work. Three things have been noticed about usage of URET: first, different sector teams use it in different ways; second, in many instances URET usage differs from what was intended; and third, the usage varies across centers. We interviewed subject matter experts to explore how controllers have adopted and/or adapted URET in three different Air Route Traffic Control Centers (ARTCC), across mentioned variations.

The goal of this research is to draw lessons from the experience with URET that can inform technology deployments in the future.

Keywords: air traffic control (ATC), automation adoption, automation adaptation, diffusion of innovation, URET, decision support tool.

1. Introduction

The objective of this research is to investigate how air traffic controllers adopt and adapt new technologies. We focus on automation for en-route air traffic controllers and facilities. The deployment of any new automation tool is motivated by anticipated improvements in system performance that are expected to result from its use. But actual improvements depend on the way controllers use the automation tools in their work. In other words, results depend on the adoption and adaptation of new technology, as well as the inherent value of the technology. We study the adoption process (that is comprised of both adoption and/or adaptation) in order to understand, (a) how and why it varies among controllers and (b) how and why the tool's use differs from pre-deployment expectations.

Automation tools or decision support tools (DSTs) have emerged as a means to overcome human operator limitations as they become more significant with growing traffic. Design of each DST is a lengthy process that requires extensive human factors research and involvement of human factors experts. As Cardosi [1] states, "early and continuous (from initial design to operational testing) of human factors issues is essential for a successful DST design." Some of the DST designs that failed (like Advanced Automation System (AAS) and Standard Terminal Automation Replacement System) [1], failed in one or the other aspect of a human factors design process and were never implemented in the operational environment. The Center TRACON Automation System (CTAS), on the other hand "in addition to doing things right from a process standpoint, CTAS also serves as an example of well-designed automated tools for controllers" [1]. Even so, it hasn't been widely spread in the Air Traffic Control system for one reason or the other. Moreover, few rigorously designed studies exist that look into how (and why) the controllers actually use the successful DST after its implementation. It is important since it seems that the good tool design is not enough for widespread use of the tool. MITRE Technical Report [2] is one of the rare papers that tackles this issue, using conversations with controllers and observations by authors as main sources for their findings. With the pending system integration of several new DSTs in the Air Traffic Control, knowing how each of them is being used is of great importance. In this context, Cardosi states: "even within a single system, integration can become an issue", and that the same process of careful consideration of: task requirements, operational environment, user characteristics and the transition to the new system;, should and can be applied to "ensure the effective integration and compatibility of separately developed systems." [1]

Researchers have also analyzed post-deployment system benefits of DSTs but again, there has been little research on the processes of controller adoption and adaptation of the deployed technology.

Each DST is deployed with certain expectations as to its use and the benefits it will provide. Deployment is a part of a diffusion process "by which an innovation is communicated through certain channels over time among the members of a social system [3]." Adoption of innovations is studied in the diffusion of innovations field, which studies various aspects of innovations adoption. Because of similarities found between general diffusion of innovation studies and the current diffusion of technology in the Air Traffic Control, we chose to use the diffusion of innovations approach in this study. The sub-process of the diffusion process is an implementation of technology. During the implementation process operators adopt, reject or re-invent (adapt)[1] technology. Adoption refers to the intended technology use, while re-invention describes the modification of an innovation e.g. using the Lotus spreadsheet as a word processor. Any implemented innovation may or may not undergo adaptation (or re-invention) by its users. Innovation adoption and/or re-invention in turn influence controller performance.

We employ the case study method in our research. The specific DST studied is the User Request Evaluation Tool, and its functionality will be described in the following section. Currently, URET has been deployed in ten Air Route Traffic Control Centers. Three things have been noticed about its usage: first, different teams use it in different ways; second, in many instances URET usage differs from what was intended; and third, the usage differs across centers as well.

The ultimate goal of our research is to analyze controller adoption/adaptation (which we will, for brevity, term "adoption" hereafter) of new technology. Here we present findings from exploratory interviews in three Air Route Traffic Control Centers of how air traffic controllers adopt URET. A rigorous, carefully designed study of URET adoption and its adaptation variation has yet to be performed.

Following section describes URET purpose and functionality. After that we describe the characteristics of innovation and how they influence diffusion. Further, we present the findings on URET diffusion that were collected in three different ARTCCs.

2. URET Description

URET is a tool designed for en-route air traffic controllers. The continental United States is divided into 20 ARTCCs, which are further divided into sectors. A sector controller team has from one to three persons, depending on the traffic induced workload. Usually, during low traffic only one controller works the sector. A second controller, and in rare cases even a third, is added when traffic and associated workload demand it. A two-person controller team consists of [4]:

- A Radar Controller (R-side), who maintains prescribed separation between aircraft under his/her control using radar-displayed information. R-side is a fully certified professional and handles all communication with aircraft.
- A Radar Associate Controller (D-side), who assists R-side controller. D-side duties cover flight strip management, coordination with other controllers, and pointing out potential conflicts between aircraft that are not yet under the active control to the R-side controller. D-side can be a fully certified professional or a developmental controller.

URET is designed as a strategic support tool for the D-side controller. Using this tool the D-side controller should be able to help the R-side controller to resolve potential conflicts of aircraft that are not yet under the sector's active control, to check if the clearances the R-side controller is issuing are conflict free, and to perform other D-side duties. The expectation is that by using the tool fully the controller team will not only be able to handle more aircraft (because of workload decrease from automation and availability of more accurate information), but will also be able to provide more direct routings and better flight profiles to airlines.

URET has an automated "conflict probe" [5] that helps controllers foresee situations when aircraft may violate prescribed separation levels of 5 nm lateral and 1000 ft (or 2000 ft above FL 280) of vertical separation. Based on flight plans and actual flight tracks, the URET system models aircraft trajectories and predicts possible conflicts up to 20 minutes into the future. To do this, URET processes flight plan and radar track data from the main computer system, called the Host Computer System (HCS). The flight plan and the track data are

[1] Terms re-invent and adapt, are used interchangeably throughout the paper.

combined with the site adaptation data (active preferred routes, active altitude and speed restrictions, etc), aircraft performance characteristics, and winds and temperature data obtained from the National Weather Service. The combined data are then used to build four-dimensional flight trajectories for all flights in-bound to or within an ARTCC. These trajectories are also projected 20 minutes in the future, and then the conflict probe function is applied to them.

The conflict probe function detects and notifies the controller of potential conflicts by showing them in the Aircraft List and Plan Display. The Aircraft List and Plan Display is one of three window-based displays of URET which automates flight strip management. It is text-based and contains the list of active and incoming flight plans, conflict probe alerts and trial plans. The trial plan is the result of the Trial Planning function; it allows a controller to check a desired flight plan amendment for potential conflicts. If the desired trial plan is conflict-free, the controller can issue a trial planned clearance to the pilot and at the same time send it to the Host Computer System as a flight plan amendment. A trial plan can be invoked either through the Route Amendment function or by clicking the changed route on the Graphic Plan Display (second URET display). The Automated Route Amendment function offers point-and-click entry of an amendment into the aircraft flight route. A controller can just click on the list of routes or list of fixes or enter its name in order to change the route. The Graphic Plan Display provides a graphic view of aircraft routes, predicted conflicts (by showing trajectories of involved aircraft), and the trial plan results. Its point-and-click interface enables quick entry and evaluation of trial plans and altitude or speed changes, as well as entry of these amendments to the Host Computer System. The Wind Grid Display shows the wind data overlaid on a sector map, thus providing information on wind speed and direction at different altitudes. The exchange of information between URET equipped ARTCCs is done through the Interfacility Automation function. This particular information exchange enables the controllers that work sectors on the center border to be aware of the incoming traffic, up to 20 minutes in advance.

At the time of this writing, URET is deployed in the Indianapolis, Memphis, Kansas City, Cleveland, Chicago, Washington, Jacksonville, Forth Worth, Denver and Minneapolis Air Route Traffic Control Centers (ARTCC). Indianapolis and Memphis were the first centers where URET prototype was deployed. The production version of URET is provided and maintained by Lockheed Martin.

3. Diffusion of Innovation

This section describes in more detail innovation characteristics that help explain the nature and rate of innovation adoption. Later on, we will present findings of interviews performed in three centers and show that these characteristics can be found in the automation adoption in the air traffic control as well.

As previously stated, diffusion of innovation "is the process by which an innovation is communicated through certain channels over time among the members of a social system [3]". Members of any social system form their opinion about adopting or rejecting an innovation through the innovation-decision process. This process encompasses the time from the first knowledge about the innovation, through the adoption (or rejection) decision, to confirmation of the adoption (or rejection) decision. In some instances, such as URET, the initial adoption decision is made at the organizational level (Federal Aviation Authority decided to deploy URET in all continental ARTCCs in USA). Individual users are then left to adopt, re-invent or reject the innovation during its implementation.

One of the factors that influences innovation adoption is the nature of a social system where the innovation is being implemented. A social system can be defined as "a set of interrelated units that are engaged in joint problem-solving to accomplish a common goal [3]". A social system develops a set of norms according to which member behavior patterns are established. Diffusion literature suggests that a difference in the norms of otherwise similar social systems can account for differences in innovation adoption. Even though the duties and goals of all ARTCCs (centers) are the same, each center has developed its own approach to achieving these goals. It will be shown in the next section that understanding center norms is essential in order to be able to understand the reasons behind the differences in different centers' automation adoption.

Further, there are five innovation characteristics that influence the nature and the rate of innovation adoption. The relative advantage of an innovation is one of these innovation characteristics, while the other four characteristics are: compatibility, complexity, trialability, and observability. The rate of adoption is faster when the advantage of using automation is clearly perceived. Here, it is the case only with the Aircraft List and Plan Display part of URET since using this display takes away manual handling of flight strips. If the automation is compatible with the task a user needs to complete, adoption will be faster. On the other hand, complexity of automation tool can inhibit adoption, or change how the tool is used (adaptation). Innovations that can be tried out tend to be adopted faster and have less problems arising. If the results from using the innovation are not obvious, adoption tends to be slower.

Innovation characteristics can lead to re-invention (adaptation) in adoption and implementation process. Re-invention describes "the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation [3]." The re-invention does not necessarily imply a negative impact. It has been noted by diffusion of innovation researchers that tools that are loosely bundled are easily subjected to re-invention. URET main functions have fairly independent use and can therefore be termed as "loosely bundled". An example of "loose bundling" is that one can use only the strip replacement function without ever having to use the trial planning function. Many controllers use only the strip replacement function, and this is considered an unwanted re-invention of URET. Another cause of re-invention by adopters can be their lack of full knowledge about the innovation. Subject Matter Experts have suggested that the training for URET use did not sufficiently explain the advantages of full use of URET (i.e., when and how to use the trial planning and what advantages it brings).

4. URET Usage

URET installation in ten ARTCCs has proceeded in three stages. First centers where URET was installed are Indianapolis and Memphis. Kansas City, Chicago, Cleveland, and Washington centers belong to the second wave of URET installation. Third ARTCC group comprises of Jacksonville, Denver, Minneapolis and Forth Worth centers. Each of these three ARTCC groups is fairly similar internally with regard to two characteristics: the length of time they have been using URET and the training they received. On the other hand, regarding any other parameter, all the ten centers are said to be fairly different and employ different social system norms, better known in air traffic control world as a "center culture". We conducted exploratory open-ended interviews with Subject Matter Experts in one center of each group. Following text describes URET adoption in each of these three centers. The order in which we present these findings does not follow the order of three aforementioned groups.

4.1 Center 1

Center 1 has been using URET for 9 years, from the prototype version to the current operational version. This center has fairly busy traffic, and the airspace structure (flows, airspaces) adds to complexity. There are many airports in and around this center and a big portion of traffic that goes through is in "transitional mode" (climbing and descending). The policy of center 1 is to try to have two-controller teams working sectors whenever possible, regardless of workload conditions. Otherwise, one controller works the sector in cases of light traffic and the D-side joins when traffic-induced workload increases.

Controllers received about 70 hours of training for prototype and production version (it was spaced out through out these 9 years). Most of the training was focused on the use of the Human Computer Interface (HCI). There were not enough examples of how to use the tool in a specific situation and what can be gained from such use. Controllers are encouraged to use URET as much as possible.

Adoption of URET in center 1 varies across controllers and in cases also varies from intended use. Aircraft List and Plan display function (that is practically electronic flight strip replacement) is the most appreciated URET function. The advantage of using it lies in reduced manual workload (no manual handling of paper strips) that frees up time for accomplishing other controller duties (i.e. coordination). It is simple to use and to update. Updates are processed through Host Computer System, which receives updates by keyboard input from either R-side or D-side, as well as from the point-and-click input from URET console. These updates are then processed and distributed to all sectors affected by this particular update. This is the fastest adopted URET functionality signaling that controllers positively perceive all 5 innovation characteristics of it.

The next most popular URET function is Route Amendment, which allows point-and-click input of aircraft route amendment to HCS. It is deemed the most useful for vectoring around weather because of the ease of amendment input (compared to amendment input from the R-side console). Using Route Amendment in such instances results in tangible benefits for controllers – they don't have to deal with a pile of paper flight strips.

Trial Plan function is also positively received even though it is not used as much as the previously mentioned functions. Obvious results from using trial planning results are ease of flight route amendment and the possibility of giving more "direct-to" clearances to pilots without causing problems to subsequent controllers by granting a "direct-to" clearance.

In contrast, Conflict Probe function is received with mixed feelings. Some controllers find it good and they tend to check all the conflict notifications. Others feel that there are too many conflict notifications (especially in the busy periods) and they often ignore them because they don't have enough time to follow through. Suggestions have been made to improve conflict probe notification algorithms to reduce number of conflict notifications and improve the information gained from them.

Center personnel stated hat URET is less compatible with ATC transitional airspace. Dynamic changes and many coordination and communication requirements are characteristics of transitional airspace. Therefore, controllers first don't have time to think about the strategic solutions; second, strategic solutions are not really applicable in an environment that is so dynamic. High altitude level flight sectors see much more URET use since the environment is more stable and allows for strategic solutions.

Another important finding is that when the controller works the sector alone, only Aircraft List and Plan display is used. The controller then generally has time only to deal with communications required. Moreover, using other URET functionalities requires use of the separate keyboard and trackball that is not convenient.

4.2 Center 2

URET has been in use for a year and a half in this center. Center 2 does not have very high traffic count but it has very complex airspace: many general aviation airports and many restricted airspaces. A fair percentage of transitional flights exist and combined with a particular mix of aircraft types contributes to complexity. This center experienced an increase in instances when controllers work alone after the start of URET use. There is no mandate for working in two-controller teams unless workload dictates it. Only the sectors where many operational errors happen are required to be staffed by a two-controller team all the time (and these sectors are few). Moreover, the center culture is more individualistic than in center 1, and the R-side position is perceived as being more important than D-side as well as being a "command position" that issues tasks to the D-side position. All the center controllers received 36 hours of training for URET use. Four hours of it was the training in the control room with the training cadre going through examples of how to use URET in specific situations. We learned that during the months needed to complete the training of all controllers the peer pressure has been used to help introduce URET usage faster. Procedure was also set that if both R-side and D-side are trained, then they can use URET and disregard paper strips which was additional incentive.

Again, as in center 1, the most popular and accepted URET function is electronic flight strip replacement because of the same reasons as in center 1.

Route Amendment function is also perceived as a very useful one, mostly when severe weather occurrences (that happen very often during summer months) impose many re-routings. An interesting use of this function occurs in this center: the Traffic Management Unit uses it to amend aircraft route (if there is a need for it from traffic flow management point of view) while aircraft is still on the ground. Controllers stated that it is the easiest way to update the flight plan affected by the traffic management decisions.

The Trial Plan function is used by some controllers, and not by others (there are more controllers who are not using it). Controllers themselves told us that the controllers that don't use it probably do so because of the center peculiarity. Having many restricted areas results in complex airspace and complex situations so controllers are taught to focus on separating traffic in their own airspace, and not to wonder about the impact their actions will have on subsequent sectors.

Conflict Probe function is used in the following way: the conflict notifications are often not looked at through the URET system (in order to learn all the details of the conflict situation), but the conflict notifications draw controllers attention to the specific aircraft and they take it into consideration. It often happens that the information from the Aircraft List and Plan display combined with the radar screen provides enough information for a controller to know where and when exactly the conflict would happen and they can take action without using URET further.

Again, there is less usage of URET full functionality in transitional sectors, and when controller works alone, most of the time only Aircraft List and Plan display is being used. On the other hand there are less and less instances in which controllers work in two-person teams.

4.3 Center 3

URET has been in use for 2 years in center 3. This is one of the busiest centers in the country that on top of the high traffic count has many transitional routes, adding to complexity. The staffing in this center is such that controllers work sectors alone most of the time. Controllers work in pairs only when the high workload dictates it, since there are not enough controllers to have two-person teams for situations other than the high workload ones. Also, a position of tracker appears in this center. The tracker position is staffed only in cases of workload so high that communicating with pilots prevents the R-side from doing any other task (coordination, typing in the route amendments and other usual tasks). In those cases the position of tracker is filled by a fully certified controller who then takes over all the other R-side duties apart from talking to pilots. He sits by the R-side in front of the radar screen and even actively participates sometimes suggesting the course of action to the R-side controller. Center 3 also received 36 hours of URET training, but with not as many examples as the center 2 had.

Again, as in centers 1 and 2, the most popular and accepted URET function is electronic flight strip replacement because of the same reasons as in center 1.

Route Amendment function is deemed useful. In contrast with other two centers controllers here say that when they would benefit from it the most (during severe weather occurrences) they don't have time to use it. The main reason for this probably lies in fact that they work alone most of the time so they are busy with other aspects of controlling traffic.

Trial Plan function is not considered useful since the controllers don't have time to use it. But, some of the developmental controllers say they use it sometimes to check planned action. It seems that it is a good learning tool for them when they work alone. On the other hand the developmental controllers say that they often don't have time to use it.

Conflict Probe notifications are not considered very useful. During training, controllers are encouraged to look for conflicting situation on the radar screen and not to rely too much on URET notification. Further, controllers report that when they are controlling heavy traffic they don't have time to look for conflict notifications on URET screen, especially since the conflict notification is indicated by coloring appropriate box. No other way of drawing controller attention is applied in URET, and that just makes the use of URET conflict notifications harder for controllers working the sector alone. Short-term conflict notification that appears on the radar screen is deemed more useful since it draws controller's attention.

There is not much use of URET in two-person teams since it rarely happens that controllers in this centers work in pairs. Furthermore, when they do work in pairs they don't have time to devote to "learning" how to use URET functionalities to their advantage.

5. Conclusions and Recommendations

The previous section shows the differences in URET adoption and adoption across three centers. It is obvious that each center has unique conditions. As a result, each of these centers has developed its own additions to control practices to be able to control traffic efficiently with respect to the particular circumstances, pointing out that indeed individual centers can be considered as separate social systems. Cardosi [1] cites a similar finding from the AAS development: "The developers of AAS found that the preferences of controllers often changed with the group of controllers…since individual preferences are based on individual experiences" which change with the environment.

These case studies provided useful insights into automation adoption in air traffic control and how this adoption relates to other diffusions of innovation. Centerwide variations in URET usage can be greatly explained by difference in norms of social systems (centers). On the other hand, team differences and unintended usage of URET result from both automation characteristics and re-invention. Automation adoption is faster when advantage of use is perceived, which has been noted to be the case with URET's electronic flight strip management capability. Adoption slows when adopters need to change their set of values in order to use the innovation. In this context, to make full use of URET functionalities, traffic needs to be controlled strategically instead of tactically. For many, this represents a change from the more tactical approach that had become more common in recent times. Change of approach has been pointed out as a difficulty by controllers. Controllers just entering the air traffic control system are coping with this better since they do not need to re-learn the strategic approach.

Re-invention appears to be quite common for many innovations. Many causes exist for re-invention of any particular innovation. Some of the causes apply in URET's case: one is "loose-bundling" of URET functions, which allows for separate function use. Another contributor to re-invention can be found in lack of full knowledge of URET's capabilities and results achieved by its full use. This can be the effect of insufficient training and/or insufficient length of tool's use. Another contributor of re-invention in some centers is a lack of situations for which URET was designed (strategic support for the D-side controller).

With the separate development of different DSTs and their pending integration into one system, it is important to know how each of them is being used, to be able to formulate a successful program for the effective integration. Having that in mind, studies of automation adoption and adaptation of different DSTs should be a prerogative.

To sum up, automation in air traffic control also follows basic principles of diffusion of innovations. Moreover, we used these principles as guidelines to form presented findings, which open up avenues for further research. We will use these findings as a basis to further develop a rigorous, carefully designed study of URET adoption. Further study will enable us to identify the most promising strategies for encouraging controller teams to use URET, as well as other DSTs in a manner that maximizes system performance and therefore the user benefits. It will also help to enrich further studies of re-invented innovations, their causes and effects.

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Biography

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