SURVEY OF TRAFFIC AND RADAR CONTROLLER COMMUNICATION AND WORKLOAD

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Introduction

Air Traffic Service (ATS) is responsible for guidance and control of flight in specific airspace. Basic obligation of ATS is to provide safe, regular and expeditious air traffic in their field of responsibility. Fulfilling of those obligations requires the division of airspace into sectors which are defined with horizontal and vertical boundaries. In each sector a team of controllers are responsible for guidance and control of flights. In Serbia and Montenegro, the controller team consists of: radar controller (RCL), procedural controller (PCL) and assistant (AST).

Radar controller is directly responsible for safe realisation of air traffic. He has insight into the traffic situation using radar screen and flight strips and communicating with aircraft pilots. The RCL's tasks consist of traffic monitoring, conflict resolution, flight guidance (vectoring), communication with pilots and other traffic controllers, etc. Realisation of those tasks creates some workload for the RCL.

This paper describes a pilot study of RCL workload and communication (as one of the basic workload generators) which was carried out in Belgrade ACC, and obtained results. For the purpose of the study, data recording and RCL questionnaires were made in March 17 and 18, 2000 (Friday and Saturday) during a 4 hour period each day (from 10.00 to 14.00 hours, local time) on sector "North East".

Recordings were made by: tape recorder in technical division of Belgrade ACC, where radio frequency, telephone and interphone traffic created by RCL on the mentioned sector is recorded, a tape recorder at the controller work position (console) which recorded conversations between RCL and PCL, video camera which is used for getting additional traffic information. In parallel with those recordings, RCL questionnaires were made. Traffic data was also available in the form of hardcopies of flight strips.

The study contains: analysis of traffic characteristics in Serbia and Montenegro airspace, analysis of communication and RCL workload (NASA TLX Method), and analysis of relationships between mentioned parameters.

Analysis of traffic characteristics

Time period of 15 minutes is used as a time unit for traffic analysis. Analysis covers the following traffic characteristics:

- cumulative number of aircraft in the sector,
- maximum number of instantaneously present aircraft in the sector,
- cumulative number of flight strips on the console,
- maximum number of instantaneously present flight strips on the console,
- total number of potential conflicts,
- total number of transfers.

Figures 1, 2 and 3 present some of the traffic parameters for Friday, March 17, 2000. In figure 1 it can be seen that the number of active strips slowly increases till 13h when it reaches value of 24, while the maximum number of instantaneously present strips on the console then was 20, which was a sign for the shift leader for activation of a new sector. After opening the new sector, the number of strips quickly decreased.

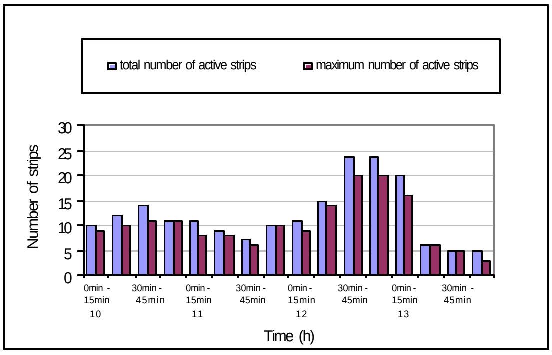

Figure 1. Number of Flight Strips (Friday)

In figure 2 it can be seen that the total number of aircraft in sector changed similarly and around 13h reaches the value of 16, while the maximal number of instantaneously present aircraft in the sector was 14. Also, it can be seen that, after opening of a new sector, the number of aircraft quickly decreases.

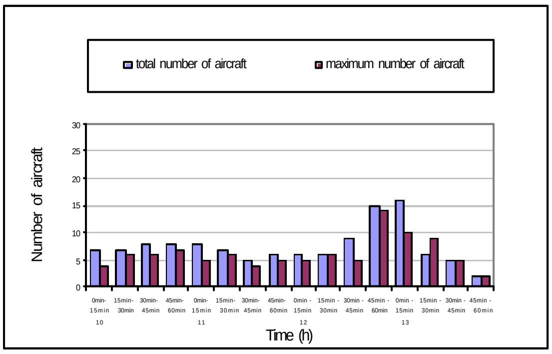

Figure 2. Number of Aircraft (Friday)

Figure 3. presents changes in the number of potential conflicts and the number of transfers (at sector entry/exit points) also for Friday. It can easily be seen that the mentioned changes follow changes presented in figures 1. and 2.

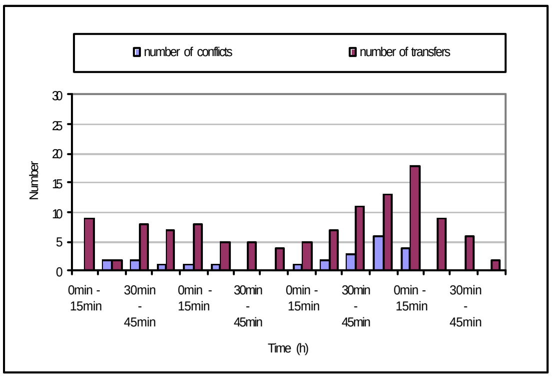

Figure 3. Number of Transfers and Potential Conflicts

Analysis of communications

During communication, the radar controller recognises pilot intentions and intentions of the other controller, and also communicates his own intentions to them. Because of that, communication requires certain "effort" on his part, which, among other controller activities, significantly contributes to increasing total workload. RCL communicate:

a) indirectly with:

- aircraft crews using radio frequency;
- controllers from neighbouring countries using telephone;
- controllers from neighbouring sectors inside Serbian and Montenegrian airspace using interphone;

b) directly with PCL from his team (Figure 4.)

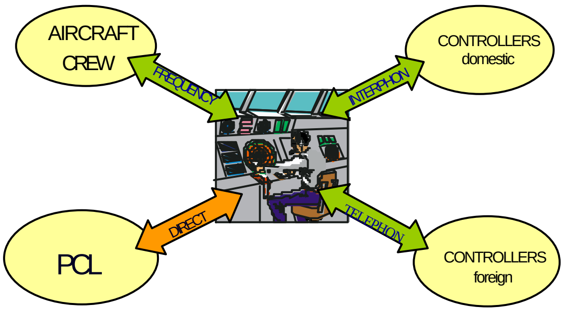

Figure 4. RCL Communication

Analysis of communication takes into account the following parameters:

- total number of RCL conversations during 15 minute intervals;
- total duration of RCL communication during 15 minute intervals;
- structure of conversation;
- average pauses between conversations.

Analysis of total number of conversations showing us (Figure 5) that most conversations are made with aircraft crews on radio frequency (62%) and then with PCL (32%).

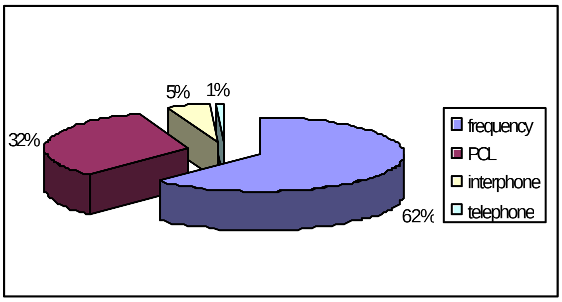

Figure 5. Structure of Total Number of Conversations

Analysis of conversation duration shows us similar (Figure 6). It was shown that most of the time is spent in conversation on radio frequency with aircraft crews (65%) and then in direct conversation with PCL (28%).

Previous analysis shows that the RCL most frequently communicates with aircraft crews and with PCL. For that reason it was decided to further examine the structures of those conversations.

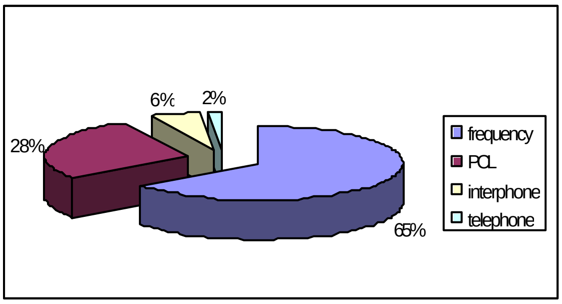

Figure 6. Structure of Total Duration of Conversations

Conversations with aircraft crews are classified in the following categories:

1) usual conversations:
   a) routine: on sector entry;
   on sector exit;
   b) non routine;
2) unusual conversations.

Analysing the structure of conversation with aircraft crews it was determined that 78% conversations are routine (38% of conversations on sector entry, 40% conversations on sector exit, Fig 7).

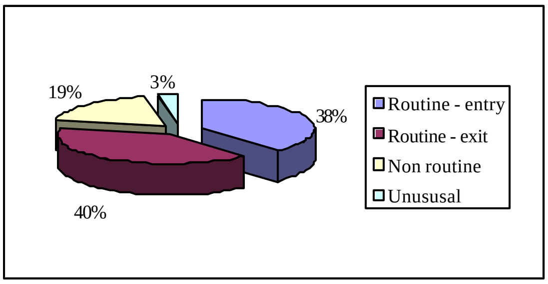

Figure 7. Structure of Conversations with Aircraft Crews

Because of highest participation in total number of conversations with aircraft crews, it was decided to analyse duration of routine conversations. It was determined that duration of routine conversations is a random variable, with average value of 15±5 seconds on sector entry and 8±3 seconds on sector exit.

Conversations with PCL are classified in the following categories:

1) conversation related to transfer/co-ordination;
2) conversation with aim of resolution of potential conflict;
3) conversation about traffic situation;
4) conversation related to departures and arrivals;
5) other conversations.

Analysing the structure of conversations with PCL it was found that RCL's most frequently talk about transfer/co-ordination (40%, figure 8) and was determined that their average duration is 7±3 seconds.

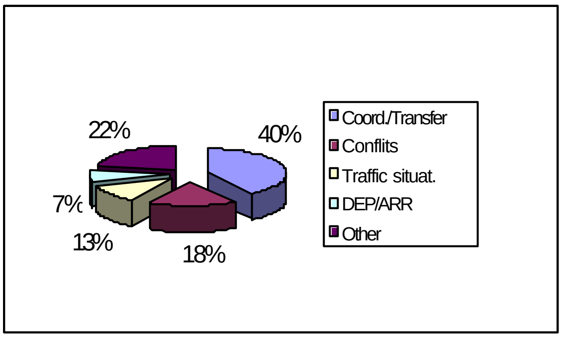

Figure 8. Structure of Conversations with PCL

A further step in analysis of communication was attempted to establish a functional relationship between traffic and communication parameters. The following tendencies are determined (according to 15 minutes intervals):

a) increase of the number of aircraft in sector produces an increase in the total number of conversations (figure 9);

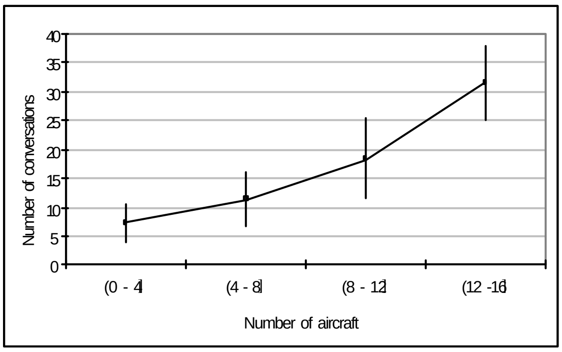

Figure 9. No. of Conversations vs. No. of Aircraft

b) increase of the number of aircraft in sector produces an increase in the duration of all conversations (figure 10);

c) increase of the number of aircraft in sector produces a decrease in the duration of all pauses, i.e. conversations are more frequent (figure 11).

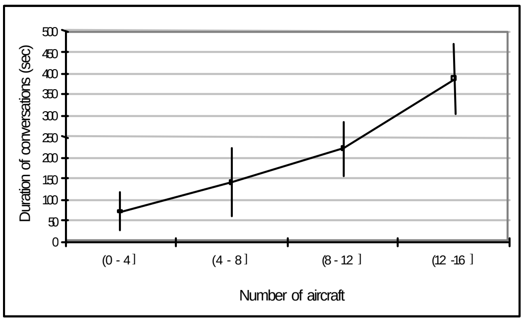

Figure 10. Total Duration of Conversations (During 15 min Intervals) vs. No. of Aircraft

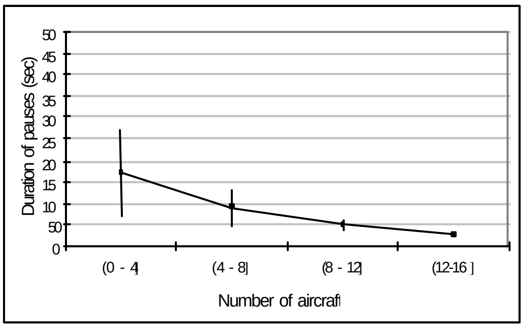

Figure 11. Total Duration of Pauses (During 15 min Intervals) vs. No. of Aircraft

Analysis of workload

Every system has limited capacities, which are determined by the capacity of some element. In a system which includes human input there is a broad spectrum of knowledge, skills and capabilities. The human element gives the system flexibility and adaptability. However humans also, bring workload, as unique human characteristics, into the system, an element that influences the capacity of the whole system. Assessment of mental workload is becoming very important for system analysis and design. In this survey, for assessment of controller workload, NASA-TLX (Task Load Index) method was used [7].

The mentioned method belongs to a group of methods which use multidimensional scales and present the outcome from a new approach in subjective measurement of mental workload. This approach assumes that mental workload is multidimensional and that the subjects are capable of reporting work requirements over each workload dimension.

Factors which were, after numerous experiments, chosen as relevant for workload assessment are the following:

- mental demand,
- physical demand,
- temporal demand,
- performances,
- frustration level and
- effort.

Each of those six factors has its own scale (figure 12).

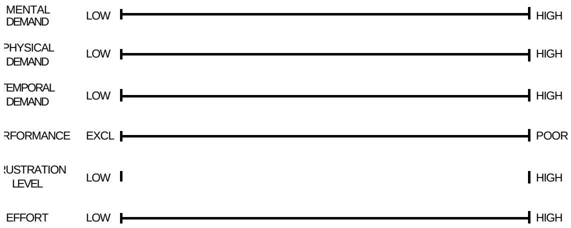

Figure 12. Scales for Assessment of Workload (NASA- TLX Method)

The relative importance of specific workload factors, i.e. weights of factors, are determined for each subject in the following way: subjects receive a questionnaire on which different pairs of workload factors are present, and it is required from them, that in each pair, they choose the factor which in that pair has more significant influence on workload. Also information about frequency of choosing some specific factor as more significant is used.

During execution of work, or after execution, subjects give estimation of values for each of six factors, by designating the appropriate place on a specific scale.

Collection and analysis of data about subjective estimation of controller workload

A few days before data collection, controllers were introduced to the look and content of the NASA-TLX scale, as well to the method of questionnaire completion. The Questionnaire is filled out during controller's work on sectors, after every 15 minutes.

For each controller the relative importance of workload factors are determined, i.e. weights of factors. After that, using a specific procedure, values of NASA-TLX workload indices for 15-minute intervals, are determined.

Data collection for this survey was made over a relatively short time period (2x4 hours), a relatively small sample of input data was collected.

For this reason, one should not go into deeper analysis and draw serious conclusions, then conclude if there is any relationship, and if there is, what kind of relationship between traffic and workload (determined using NASA-TLX method) exists.

Comparing the cumulative number of active strips, or number of aircraft in sector with appropriate workload index, a relationship could be determined. From other side, significant individual differences between controllers was found. Namely, for the same or similar number of strips or aircraft, together with similar number of transfers and potential conflicts, for different controllers quite different values of workload indices are obtained. Moreover, cases exist, when for large number of strips or large number of aircraft in sectors, some controllers give significantly lower workload estimates than other controllers, which are at the same time responsible for a lower number of aircraft. Because of the mentioned obvious individual differences, it was decided that comparative analysis of traffic and workload index should be presented by the controllers and not in time scale.

In figure 13. the cumulative number of active strips, number of potential conflicts and workload index are presented (NASA-TLX), and in figure 14. the number of aircraft in sector, number of potential conflicts and workload index, for Controller No.1. Potential conflicts are shown in both cases, because they could present explanation for possibly high values of workload indices, in situations when the number of strips or number of aircraft in the sector could not justify those values. Here it should be mentioned that workload index is presented in a different scale, and the index values should be read from separate axes.

Similarly, in figures 15. to 20. comparative analysis for the rest of controllers is presented.

One characteristic occurrence could be found for <u>Controller No.1</u>: in first 15 min of work on sector he gave a non proportionally high workload estimation in regard to the rest of 15 min intervals. It would be very interesting to see if this occurrence would continue after longer questionnaire (few days). With this exception, this controller could be said (in the authors opinion) to be giving “logical” workload estimates.

For <u>Controller No.2</u> pretty low workload estimation is characteristic (in the authors opinion, even unreasonably low), e.g. for 24 strips on console, 15 aircraft in sector and 6 potential conflicts (Friday, 12:45-13:00), controller gives the workload estimation such that workload index is 22 (on scale between 0 and 100). Question is raised: how complex would the traffic situation have to become, for Controller No 2 to estimate workload close to the upper scale boundary (value of 100)?

<u>Controller No.3</u> answers during the hour with low traffic intensity (maximum 9 strips and 7 aircraft in sector) and without potential conflict situations. This traffic situation influences the controller’s workload estimates, so that obtained values for workload indices for all 15-min intervals are 5.

In case of <u>Controller No.4</u> there was a pretty clear relationship between traffic parameters and value of workload indices, although values are probably a little lower than real (as with Controller No.2).

The presented comparative analysis of traffic vs. workload index values could be used for two purposes:

- to show if the method used for subjective workload estimation (NASA-TLX), is sensitive to objective changes in controller workload, and
- to find a functional relationship between traffic parameters and workload, for purpose of workload prediction. Regarding the mentioned, traffic parameters (for which possibility to obtain them in shape of traffic forecast exist), should be used. Such parameters are, for example, number of aircraft in sector, data which could be provided to the dispatcher very precisely (according to data from flight database: FDPS - Flight Data Processing System).

In figure 21. the relationship between workload index value and number of aircraft in sector (defined based on data from described experiment) is presented.

Figure 22. also presents the relationship between workload index value and number of aircraft in sector, but classified according to number of aircraft. For each class (until class 11,12) average value and variance of all workload indices, are determined. For class 13 and 14 aircraft there is no data, and for classes 15,16 and 17,18 individual values are shown.

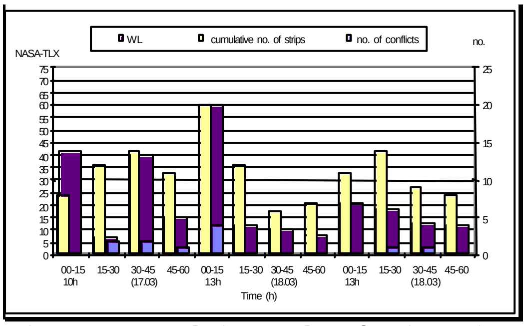

Figure 13. Cumulative Number of Active Strips, Number of Conflicts and Workload Indices Controller No.1

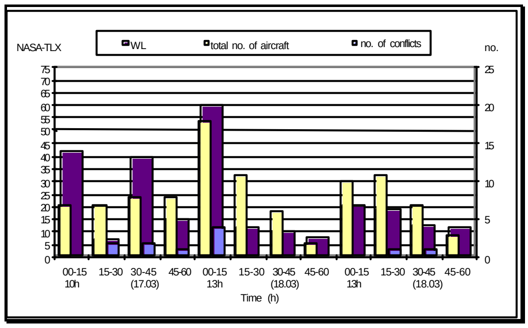

Figure 14. Number of Aircraft in Sector, Number of Conflicts and Workload Indices Controller No.1

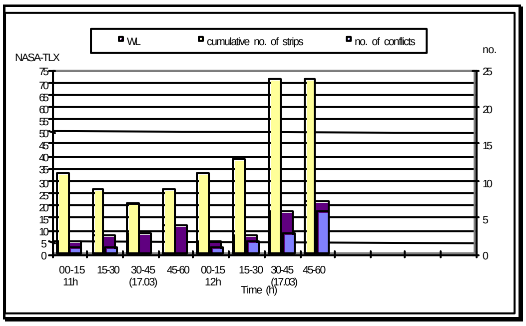

Figure 15. Cumulative Number of Active Strips, Number of Conflicts and Workload Indices Controller No.2

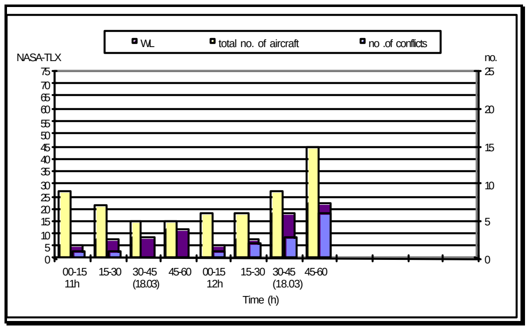

Figure 16. Number of Aircraft in Sector, Number of Conflicts and Workload Indices Controller No.2

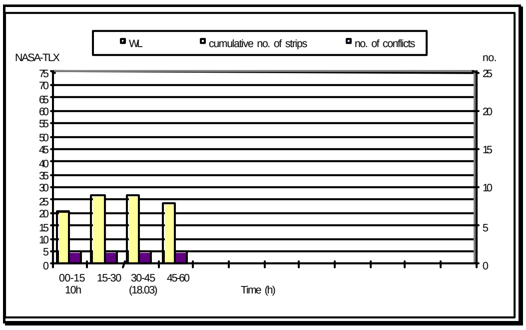

Figure 17. Cumulative Number of Active Strips, Number of Conflicts and Workload Indices Controller No.3

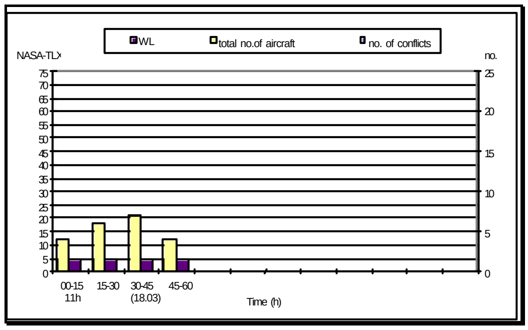

Figure 18. Number of Aircraft in Sector, Number of Conflicts and Workload Indices Controller No.3

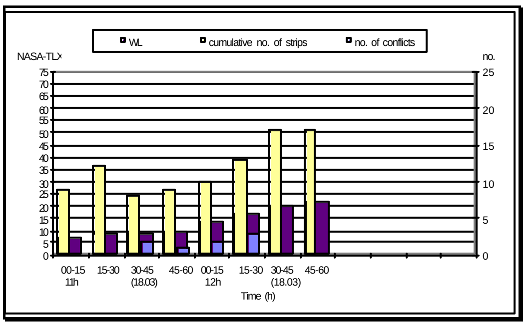

Figure 19. Cumulative Number of Active Strips, Number of Conflicts and Workload Indices Controller No.4

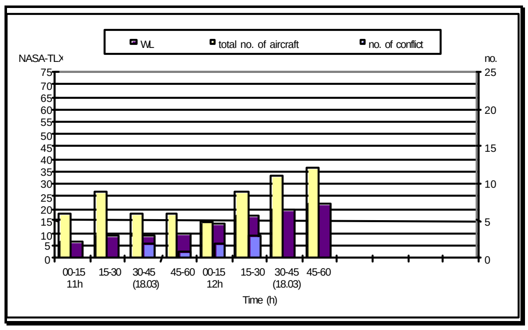

Figure 20. Number of Aircraft in Sector, Number of Conflicts and Workload Indices Controller No.4

Functional relationships of this type could help a dispatcher during decision-making about opening of new sectors (if in a given traffic situation high value of workload is expected), or closure of sectors (if expected workload is low). Here it should be emphasised that the obtained functional relationships do not present only the relationship between workload and a chosen traffic parameter, they also carry the information about influence of other factors on controller workload (the controller estimates workload not only based on the chosen traffic parameter but regarding total traffic and the global situation in sector).

Based on data analysis about subjective controller workload estimation, as well as comparative analysis of traffic parameters and workload, it was concluded that:

- NASA-TLX scale is sensitive on objective changes of controller workload,

- significant individual differences between controllers in understanding of workload, as well as workload estimation, are not avoided using this method,

- relationship between traffic parameters chosen for comparative analysis (cumulative number of active strips, number of aircraft in sectors, number of potential conflicts) and workload index exists, but dependence is not direct.

Detailed analysis and making valid conclusions requires collection of a greater amount of data, covering more traffic situations, i.e. to record hours with different traffic intensity.

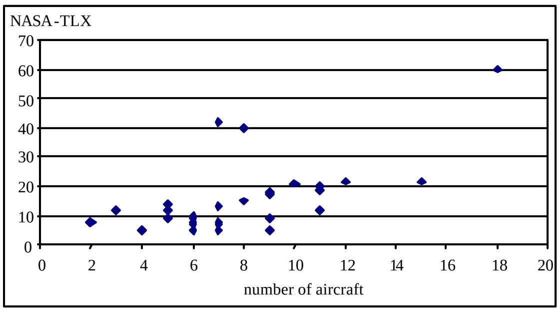

Figure 21. Workload Index vs. Number of Aircraft in the Sector

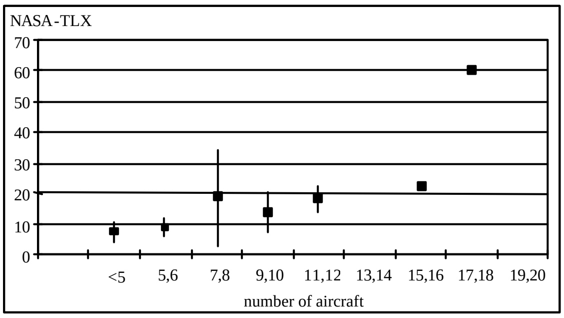

Figure 22. Workload Index vs. Number of Aircraft in the Sector – Classes

Comparative analysis of communication and RCL workload

Further analysis contains a comparison of obtained RCL communication parameters and subjectively estimated RCL workload. The aim of this comparison was to examine the connection between changes of communication parameters and changes of estimated workload (determined through NASA – TLX index) during 4 hour periods for both days during which recordings and questionnaires were made.

On figures 23. and 24. are presented changes of number of conversations and workload index for Friday and Saturday (scale on axes is common for both variables). It can be seen that a certain relationship between changes of both variables during analysed time period exists.

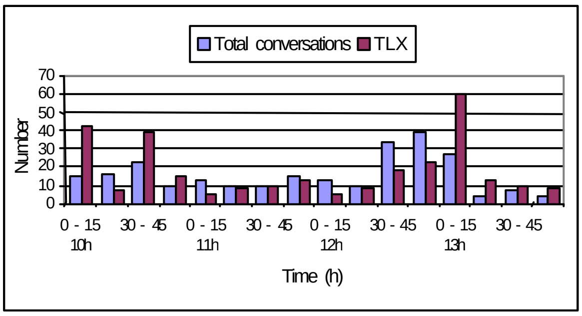

Figure 23. Changes of Number of Conversations and Workload Index (Friday)

on the situation is similar in figures 25. and 26, which show changes of conversation duration and workload index for Friday and Saturday. Here it is also possible to see that a certain analogy between changes of both variables during the analysed time period exists.

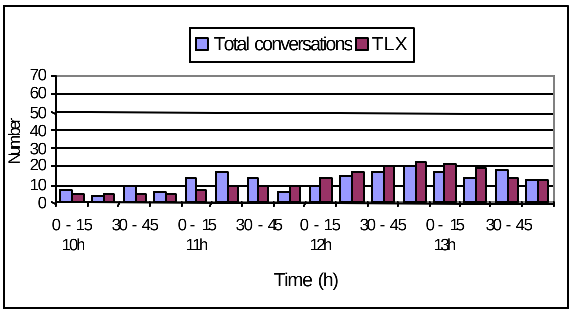

Figure 24. Changes of Number of Conversations and Workload Index (Saturday)

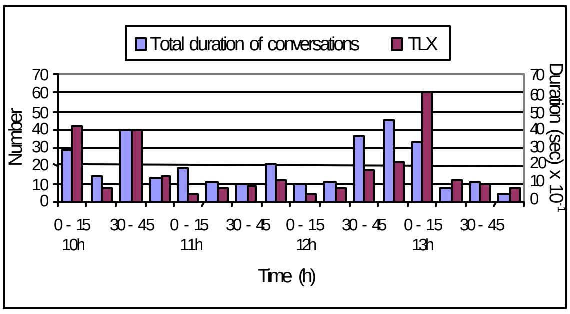

Figure 25. Changes of Duration of Conversations and Workload Index (Friday)

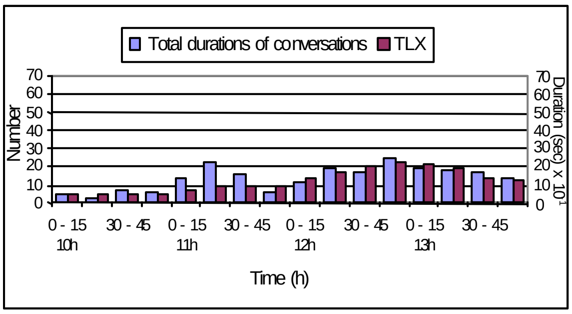

Figure 26. Changes of Duration of Conversations and Workload Index (Saturday)

According to the obvious visual similarities between changes of communication parameters and workload indices it was attempted to establish a functional relationship between analysed parameters. Correlation is used for determination of relationship but regression is not made because the data sample was too small. The relationship was presented in figures 27. and 28. It can be concluded that certain trends exist, i.e. that the increase of a communication parameter (number or duration of conversations) produces an increase of workload index value.

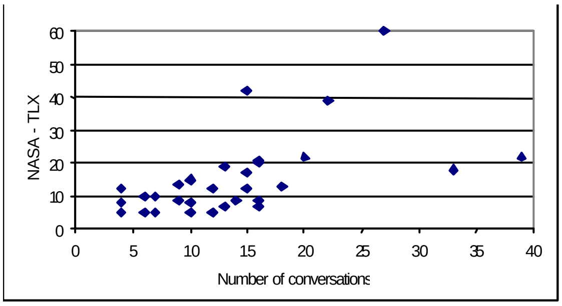

Figure 27. Workload Index vs. Number of Conversations

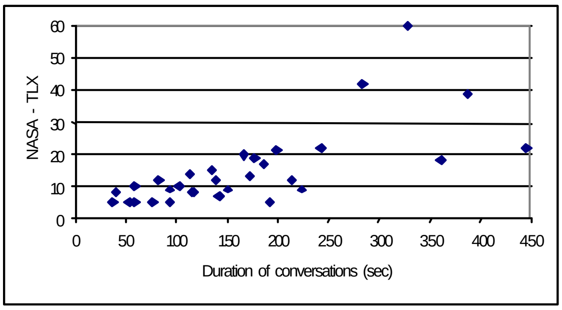

Figure 28. Workload Index vs. Duration of Conversations

Conclusion

The purpose of the presented survey was to determine the engagement of the radar controller in communication, from one side, and from the other, to determine how this engagement influences estimated workload.

Analysis of conversation structure was made and it was found that radar controller most frequently communicates with aircraft crews and then with procedural controller.

Moreover, it was attempted with analysis to establish a relationship between workload and communication parameters (number of conversations or duration of conversations). It was concluded that communication is an important factor influencing controller workload, i.e. that increases in the number and duration of conversations lead to workload increase.

During the research it was also concluded that the NASA - TLX method for estimation of workload is sensitive to objective changes of controller workloadad.

Here it should be emphasised that results are obtained on the basis of a pilot survey and that they should not be generalised. Because of that, the continuation of the survey, appears a logical step, with the aim of increasing the sample, which will enable determination of a functional relationship between workload and communication parameters. Also a very important issue is to see the impact of new communication technology (e.g. data link) on communication parameters and finally on workload.

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Biography

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