

9 factors are used to calculate dynamic density. It is assumed that different types of clicks were associated with different amount of ATCO load and i4D equipage does contribute to airspace complexity.

In all models, a linear regression function has been considered to relate the complexity of airspace measured by complexity factors to a parameter describing taskload. The intention was to find a good taskload model by examining to which extent the measured complexity in the airspace correlates with controller's taskload. In each model, a set of parameters have been used to shape the independent variable X and the dependent variable Y. The main difference between the model of [3] and the ones developed in the current work lies in the definition of Y. In [3] controller pilot data link communication (CPDLC) has been first considered as workload measure. Then the workload model has been improved by adding the controller-pilot voice communications to CPDLC activities (Model A). Then, in the next step radio calls durations (frequency occupancy time in 2-minutes time step) and average duration of single calls were calculated and added to CPDLC activities and were considered altogether as the improved taskload model (Model B).

As can be seen in Table III, in models 1-a and 2-a the same 8 complexity factors as the ones presented in [3] has been considered as X, but two different measures has been used to configure taskload. Similarly, in models (1-b and 2-b) the same complexity factors plus i4D equipage (9 factors) are considered as X, but again two different measures has been used for shaping taskload. In models 1-a and 1-b, different types of clicks are assumed to have the same load applied on the controller. But in models 2-a and 2-b, tasks are differentiated and different weights are given to different tasks.

In fact, the goal of developing models 1-b and 2-b was to examine whether automation equipage level could better explain the controllers' taskload while the goal of developing models 1-a and 2-a was to improve taskload model by differentiation between various type of tasks. In models 1-a and 2-a, clicks have been differentiated based on their type and different weights have been assigned to different types of clicks. For example, in SCN-1-50%, there are 56 different tasks. All tasks are classified into four different types based on [4]; background tasks, control tasks, transitioning tasks and recurring tasks. The task classification in each scenario has been performed manually according to the information provided in the log data.

In all scenarios for each 30-seconds time step, the taskload is calculated using the formula presented in [4].

$$Y = \lambda_b \times \tau_b + \lambda_c \times \tau_c + \lambda_t \times \tau_t + \lambda_r \times \tau_r$$

where

τ_b : typical duration of a background task = 2 seconds

τ_c : typical duration of a control task = 50 seconds

τ_t : typical duration of a transitioning task = 10 seconds

τ_r : typical duration of a recurring task = 3 seconds

λ : frequency of tasks in 30 seconds time step

At the end, a dimensionless value is obtained for the taskload for each sector at each time step. Then a linear regression was made between complexity factors and the taskload values using the general form of the formula bellow:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n$$

Because there are different X and Y functions considered in each model, different values for β are expected in each model. Therefore, models are compared to each other on the basis of regression analysis factor R^2 .

VII. RESULTS AND ANALYSIS

The complexity factors were calculated on 18 set of simulations, each taking 90-120 minutes. Each complexity factor as well as the number of clicks and taskload have been calculated over each 30-seconds time step. As a result, a total number of 2077 data points were available for the regression analysis for each sector. Since not enough clicks were made on all sectors in all scenarios, the results for only sector 3 and TMA-W are analyzed. Table IV and Table V compare R^2 between the four taskload models of this work with the two of [3] for sector 3 and TMA-W respectively.

TABLE IV. STATISTICAL COMPARISON BETWEEN FOUR MODELS OF THIS WORK IMPLEMENTED ON SECTOR 3 AND THE TWO OF [3].

Models	A	B	1-a	1-b	2-a	2-b
R^2	0.13	0.16	0.19	0.22	0.62	0.63

TABLE V. STATISTICAL COMPARISON BETWEEN FOUR MODELS OF THIS WORK IMPLEMENTED ON TMA-W AND THE TWO OF [3].

Models	A	B	1-a	1-b	2-a	2-b
R^2	0.13	0.16	0.12	0.12	0.84	0.82

As it is seen from Table IV, R^2 in the model of [3] has improved by 3% while in this work, by going one step forward from clicks to taskload, around 40% improvement in R^2 is achieved. By comparing the R-square between the taskload model 2-a with 2-b, it is seen that i4D equipage does not very much affect complexity of en-route airspace.

As can be seen from Table V, an improvement from clicks to taskload model has resulted in more than 70% increase in correlation factor. By comparing the R-square between the taskload model 2-a of sector 3 with 2-a of TMA-W, one can conclude that the taskload model better correlates with airspace complexity in terminal airspace than in en-route airspace. Both Table IV and V show that i4D equipage does not contribute to a better correlation between airspace complexity and ATCO taskload in both en-route and terminal airspace.

