Development of future scenarios by prediction of mental workload in a traffic management control room

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Abstract. Existing instruments to investigate mental workload are dedicated to specific and existing monitoring jobs. Objective instruments mostly focus on performance or physiological measures. Subjective instruments are more simply applicable, but not suitable to predict mental workload in a nonexistent situation. To overcome these disadvantages Intergo developed OWAT™ (Objective Workload Assessment Technique) to assess mental workload of operators in control rooms. A case study shows the use of OWAT™ in development of scenarios for the near future of the traffic management control room of the city of Amsterdam. Prediction of workload was key issue in this scenario development.

Keywords. Mental workload, prediction, traffic management, control room

1. Introduction

Existing instruments to investigate mental workload are dedicated to specific and existing monitoring jobs and tasks. Generally it takes months of preparation on analysing employee's activities before the assessment of the tasks can start. Objective instruments focus on performance or on physiological measures. More generic and simply applicable instruments are subjective instruments. These are not applicable to predict mental workload for nonexisting jobs or situations not existing yet. To overcome these disadvantages Intergo developed OWAT™. This paper describes the assessment of workload in the current situation and the development of future scenarios. Also, workload in future scenarios was calculated using OWAT™.

2. Assessment of workload in current situation

2.1 Traffic management control room of the city of Amsterdam

The job concerning is the traffic manager in the traffic management control room of the city of Amsterdam. This traffic management control room monitors traffic in the city center of Amsterdam and traffic on several routes into the city center. There are 2 bigger tunnels and 2 smaller tunnels, which have to be monitored with special focus on tunnel safety and free flow of traffic through these tunnels. There are currently 3 monitoring desks in the control room. Each monitoring desk has its own video wall, tunnel control systems per tunnel, and several communication systems. Figure 7 shows schematically the layout of the current traffic management control room.

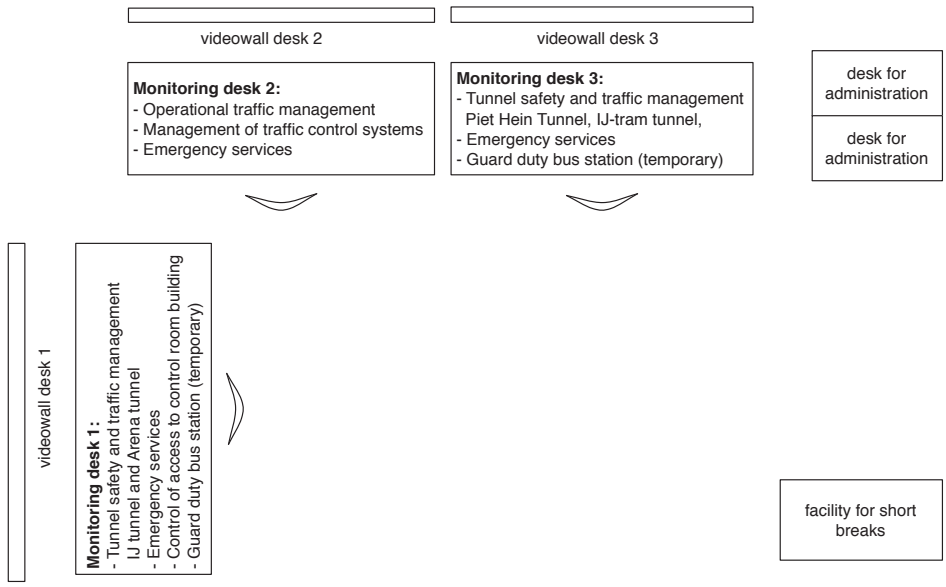

Figure 7:schematic lay-out of the current traffic management control room

2.2 Workload assessment tool: OWAT™

Intergo developed a workload assessment tool in order to overcome disadvantages of other assessment tools. This tool is called Objective Workload Assessment Tool (OWAT™). OWAT™ is based on the VACP method, developed by McCracken and Aldrich (1984). VACP represents the 4 modalities of human information processing: visual, auditory, cognitive and psycho-motoric. The development of OWAT™ is described in Weeda and Zeilstra (2013). OWAT™ uses normative limits for overload and underload and distinguishes long lasting workload and peak workload.

2.3 Assessment of mental workload in current situation

At the start of the project a project team was formed with a representation of traffic managers and senior management of the traffic management control room. First step was to investigate historic data to determine which occasions could be representative for workload calculations for the current situation. Based on task descriptions, training documentation and historic data a clustering of tasks was made, which could be representative for all tasks in all tunnels. Each cluster of tasks (see

Table ***4***, second column) described a certain occasion that requires action of a traffic manager.

Together with the project team of traffic managers each cluster of tasks is assessed for aspects related to information processing activities and scored with OWAT™. Ranking of clusters of tasks, based on OWAT™ scores, is shown in third column. The cluster of tasks indicated with 1st is most demanding for mental workload, the task indicated with 10th is least demanding. The OWAT™ scores of the clusters of tasks were validated using SWORD (Subjective Workload Dominance (Vidulich et al, 1991)). The result of this validation in terms of ranking is also shown in

Table 4, fourth column. The correlation coefficient between OWAT™ scores and SWORD scores on group level was 0,97 (Pearsons product moment correlation Coefficient). Differences in ranking could be interpreted by taking the amount of routine and the experienced user-friendliness of various systems into account.

Table 4: Ranking of clusters of tasks of the traffic managers

No.	Description of cluster of tasks	OWAT™ Ranking	SWORD Ranking
1	Monitoring of traffic on video wall	10th	9th
2	Disturbance in ventilation system	8th	8th
3	Request for free lane emergency services	4th	4th
4	Pile-up in a tunnel with a few slightly injured motorists	1st	1st
5	Announcement of traffic congestion in a tunnel	5th	6th
6	Announcement of too high vehicle entering a tunnel	2nd	2nd
7	Traffic detection without need for further activities	9th	10th
8	Failure of traffic light, priority 1	6th	5th
9	Preparation of traffic management text boards using a scenario	3rd	3rd
10	Request to police for regulation of traffic at a crossroads	7th	7th

The traffic managers described two imaginary but realistic cases of two hours of work, one during normal rush hours (7.30 a.m. till 9.30 a.m.) and one for a disturbance during rush hours. Both cases were based on historic data over the last year and traffic managers made use of the defined clusters of tasks. The OWAT™ scores for each cluster of tasks were projected on the cases to predict the workload in both cases. Predictions of workload were weighted against the normative limits of OWAT™.

Table 5 shows results of the calculation of workload and staffing per tunnel monitoring desk during rush hours without disturbances and during rush hours with disturbances.

Table 5: Workload and staffing for several monitoring desks – current situation

Desk	Rush hours WITHOUT disturbances		Desk	Rush hours WITH disturbances	
	Workload with OWAT™	Staffing (completed)		Workload with OWAT™	Staffing (completed)
1	155	1	1 + 2	318	1
2	123	1			
3	132	1	3	280	1
TOTAL	410	3	TOTAL	598	2

Figure 8 shows the results of OWAT™ calculations during rush hours without disturbances for a specific monitoring desk. In these situations traffic managers have to monitor traffic in the direct vicinity of the tunnel and in the tunnel itself and they have to react on certain alerts regarding traffic management systems. Calculations showed that workload is acceptable during rush hours without disturbances. During a disturbance the traffic managers have to safeguard tunnel safety by manipulating tunnel installations and traffic management systems. They also have contact by phone with emergency services and local assistance personnel. Calculations showed that at the beginning of a disturbance, workload would be unacceptable for one traffic manager, but two can do the job using a certain prioritization in the execution of tasks.

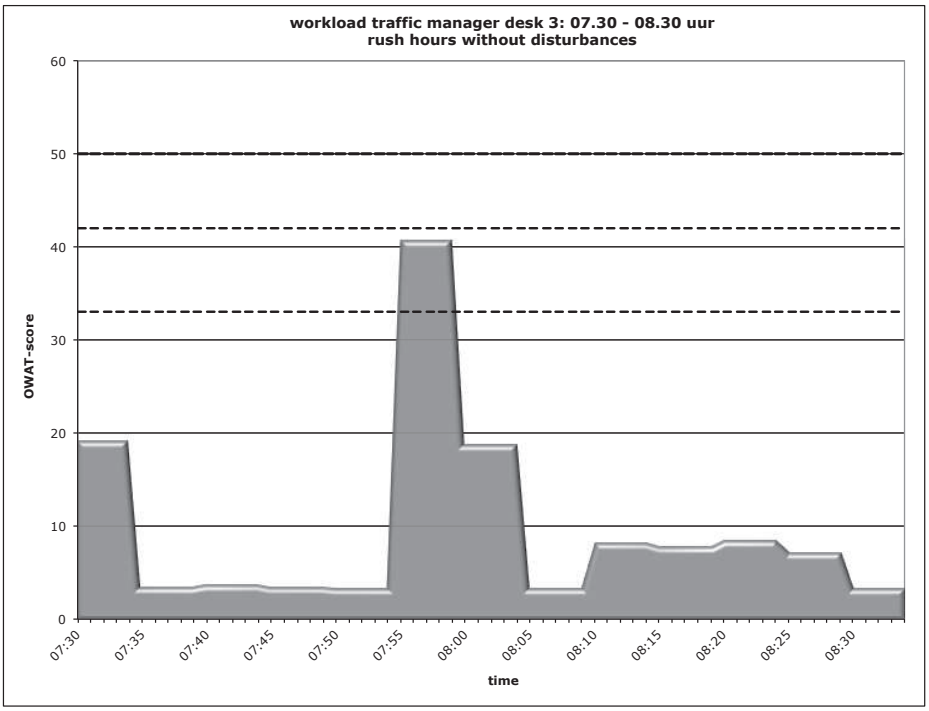

Figure 8: Workload for a traffic manager during rush hours without disturbances (desk 3)

Note in Table 5 that staffing during rush hours with disturbances is smaller than staffing during rush hours without disturbances. During described disturbances one of the traffic managers leaves the traffic management control room to provide assistance at one of the tunnels. The other two traffic managers take over his monitoring desk. Staffing with two traffic managers during disturbances can be acceptable during limited time when using rules of prioritization and collaboration in order reduce peak load. These rules result in temporary decrease in traffic management in the city, but guarantee the focus of traffic managers on tunnel safety. Ergonomic disadvantages caused by limited staffing during situations with disturbances, especially regarding monitoring two video walls instead of one and controlling systems of two monitoring desks instead of one desk, are acceptable when duration is limited.

3. Future scenarios for the traffic management control room of the city of Amsterdam

Definition of future scenarios was mainly based on progress in development of new tunnels in the city of Amsterdam during the period of 2014 till 2018. Question was whether current staffing of the traffic management control room could monitor these new tunnels and safeguard tunnel safety in these tunnels.

First step in detailing future scenarios was again to investigate historic data with special scope of possible simultaneous occurrence of occasions that require action of a traffic manager. Together with the project team estimations about future possible simultaneous occurrence were made, based on trends in traffic growth in the city of Amsterdam and based on trends in historic data mentioned.

Second step was to describe developments on several fields of interest, regarding the work organization of the traffic management control room, modernization and expansion of tunnel installations, changes in tunnel safety and control systems (from analogue to digital control), and expansion of the areal of traffic management equipment. Also

collaboration with other traffic management control rooms was considered.

Third step was to project results of the first two steps on each new tunnel in order to determine impact of commissioning of these tunnels during the period of 2014 till 2018. Results were translated in most likely occurrence of clusters of tasks as defined earlier in the project (

Table ***4***). In this step workload calculations were made for each new tunnel and again for 2 situations: rush hours without disturbances and rush hours with disturbances.

Fourth step was to investigate which current monitoring desk from the perspective of workload could manage a new tunnel. Special emphasis was on the assessment of the feasibility to monitor traffic in the several tunnels by one traffic manager at one monitoring desk. Together with traffic managers, this combined monitoring of tunnels was explicitly modelled and scored with OWAT™.

For rush hours without disturbances there was not a clear preference, which desk could manage one new tunnel or even both new tunnels. But during rush hours with disturbances, there was a clear preference, based on the chance of long lasting mental overload and the chance of peak load. Conclusion was that the first new tunnel, commissioning foreseen in 2014, could easily be integrated on the current traffic management control room. For commissioning of the second new tunnel, as foreseen in 2018, an extra monitoring desk would be necessary. Table 6 shows results of calculations for the chosen future scenarios for the year of 2018.

Table 6: Workload and staffing for several monitoring desks – future situation 2018

	Rush hours WITHOUT disturbances Future situation: 2018			Rush hours WITH disturbances Future situation: 2018	
Desk	Workload with OWAT™	Staffing (completed)	Desk	Workload with OWAT™	Staffing (completed)
1	155	1	1 + 2 expanded	365	1
2 expanded	123	1			
3 expanded	190	1	3 expanded	347	1
4 new	48	1	4 new	150	1
TOTAL	533	4	TOTAL	862	3

Also for the future situation it should be noted that staffing during situations with disturbances is smaller than staffing during situations without disturbances. Limitations and preconditions for acceptability of this limited staffing during disturbances are the same as described for the current situation, see chapter 2.3. Workload for desk 4, especially in situations without disturbances but also in situations with disturbances, will be low, so underload will be likely. The management of the traffic management control room considers this as an opportunity for higher ambition in traffic management across the city of Amsterdam.

A layout of the future traffic management control room was designed, based on the chosen future scenarios, see Figure 9.

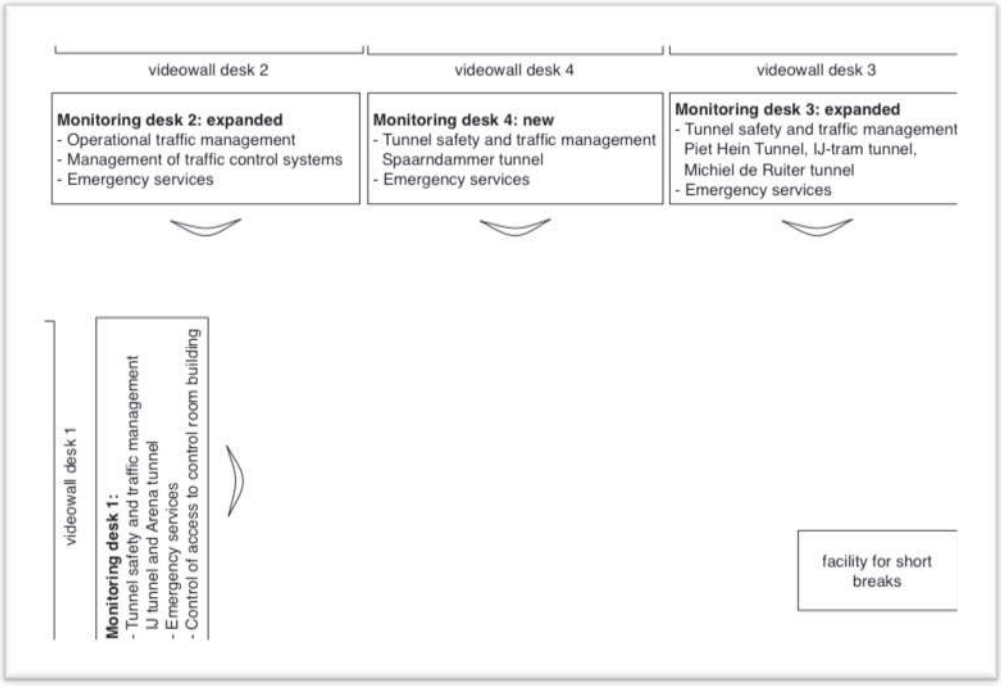

Figure 9: schematic lay-out of the future traffic management control room

4. Discussion and Conclusion

Traffic managers in the project team agreed with the results of workload assessments with OWAT^{TM} in both cases described. The highly participative way of assessment of workload was appreciated. They recognized their own job in the assessment, in contrast with earlier assessment of workload with a far more limited tool based on frequency of occurrence of observable psycho-motoric activity. OWAT™ emphasizes cognitive activities, which better suits monitoring tasks in control rooms.

The OWAT™ assessment made it possible to point out the bottlenecks in workload and relate them to certain circumstances. Also various future scenarios could be suggested, using the description of the cases, the numerical calculations and the figures, resulting from an OWAT™ assessment. Management of the traffic management control room was pleased with the results, because the results showed that there was an opportunity for a higher ambition in traffic management in the city of Amsterdam. This was against expectations at the start of the project, but the results of the assessment were clear and there was full support of all traffic managers for the results of the assessment.

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