DEVELOPMENT AND IMPLEMENTATION OF A PREDICTIVE TOOL FOR OPTIMIZING WORKLOAD OF TRAIN DISPATCHERS

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Abstract
In the past Dutch rail infrastructure manager ProRail used only 1 instrument concerning workload of train dispatchers. This instrument was called BVO. Evaluation of BVO by Intergo learned that it wouldn't suite as sole instrument to optimize workload of train dispatchers. Based on a workload model ProRail nowadays has 3 instruments to investigate workload of train dispatchers. One of them is Task Weighing™. Scope of Task Weighing™ is the objective amount of work of a train dispatcher. Task Weighing™ is being used together with an instrument regarding individual subjective workload and one regarding working environment.
Development of Task Weighing™ took place in a highly participative way. Task Weighing™ incorporates modern insights about workload. Also current working methods and use of the current automated systems are now part of Task Weighing™. Highlights of the development of Task Weighing™ are presented. Task Weighing™ is a calculating formula, which can be used for prediction of workload.
Until now Task Weighing™ is used to predict workload for several railway yards in Holland. A case study shows the interaction between the 3 workload investigation instruments. Results of Task Weighing™ calculations are recognized as representation for workload of train dispatcher during rush hour and during a disturbance. The 3 instruments together make the discussion about the sensitive issue of workload more objective and point to recognizable solutions for optimizing workload of train dispatchers.

Keywords: task weighing, workload tool, workload optimization, train dispatchers

1. Introduction
The Dutch rail network manager ProRail strives for an optimal workload for its train dispatchers. Ensuring safety and quality of work of train dispatchers, as well as optimal use of human resources and proper working conditions are reasons for this ambition.
In the past ProRail used only 1 instrument concerning workload of train dispatchers. This instrument was called BVO. BVO had its roots in the introduction of automated train dispatching systems, mid 1980's. Evaluation of BVO by Intergo learned that it wouldn't suite as sole instrument to optimize workload of train dispatchers. The approach of workload in BVO was outdated and didn't justify workload as a multi-dimensional concept.

2. The concept of workload
In literature there are several terms and concepts regarding workload. Words like working pressure, workload, taskload, mental strain, stress etc. are used and there seem to be no clear definitions. Even in international standards there are differences in terms regarding workload.

Term	Meaning	Reference to standard
Mental strain	The immediate effect of mental stress within the individual (not the long-term effect) depending on his/her individual habitual and actual preconditions, including individual coping styles.	ISO 10075 (1991)
Mental stress	The total of all assessable influences impinging upon a human being from external sources and affecting it mentally	ISO 10075 (1991)
Work strain	Internal response of the worker to being exposed to work stress depending on his/her individual characteristics (e.g. size, age, capacities, abilities, skills, etc.)	ISO 6385 (2004)
Work stress external load	Sum of those external conditions and demands in the work system which act to disturb a person's physiological and/or psychological state	ISO 6385 (2004)

Table 1 Terms regarding workload in some international standards

The lack of a clear definition of workload causes unintelligibility about what is really meant when discussing workload. Also workload often is a emotional subject, in many companies related to labour standards, especially salary. Of course unclarity doesn't help in discussing workload in a rational way.
To avoid the unintelligibility mentioned above a model of the concept of workload is developed, based on ISO 10075 (1991). Determining or predicting workload is more than only determining how many tasks (in this case) a train dispatcher performs, and how much time this takes. Besides the task itself there is a working environment and the subjective experience of performing a task. These 3 are tightly connected to each other. Result is a certain quality of task performance. Table 2 and figure 1 illustrate this model.

WORKLOAD		
Task demands or task performance	**Experience of workload (subjective/individual)**	**Working environment (objective)**
Examples:	*Examples:*	*Examples:*
- Amount of work - Variation in complexity - Quality - Speed of task performance - .. - .. - .. - ..etc.	- Competencies - Stress resistency - Coping - Commitment - Private circumstances - Individual differences - .. - ..etc.	- Possibilities for regulation of task fulfilment - Managementsupport - Social pressure - Procedures/ intelligibility - Managementstyle - Salary - ..etc.

Table 2 Influences on workload (based on ISO 10075, 1991)

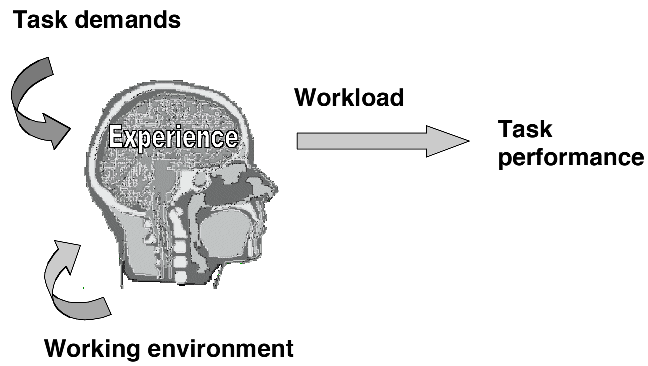

Figure 1 The model of workload (based on ISO 10075, 1991)
Input for the resulting task performance are the task demands and the working environment. Task demands as well as working environment are influenced by the way a human experiences the situation. The latter is connected to characteristics of that human like knowledge, task experience etcetera. This all causes a certain workload. The human delivers a certain output: the way the task is performed. For train dispatchers safety is an important aspect of task performance.

3. Development of the predictive tool Task Weighing™

3.1 History
With respect to the automation of train dispatching systems in the mid 1980's there was a need for a tool with which an indication of the number of necessary train dispatchers could be calculated. This tool was called BVO (Lenior, de Bruijn, 1997). BVO is based on an extended task analysis with 5 base task components:
1. Monitoring trains;
2. Control by preparation of routes;
3. Communication by short messages;
4. Communication by (longer lasting) consultation;
5. Adjustment of the plan.
Physical or mental demands are incorporated in each task component or in weighing of activities in each task component. BVO calculates the workload in a normal, rush hour and in a disturbed situation on the track. Result of the calculation is a number of points without unit. Thorough comparison of situations and constant evaluation of BVO resulted in a tool that had a sound prediction of necessary workforce as outcome.

In the 1990's a major change in the rail sector in Holland was carried through, which resulted in an infrastructure management company and a train operating company. Train dispatching changed of course also, and still is changing: new tasks came in, other tasks were outsourced to the train operating company or were even not necessary any more. Questions arose as to the applicability of BVO in this new situation. Use of BVO was not comprehensible although recorded.

With regard to the presented workload model in chapter 2 BVO is evaluated and compared with more recent insights about workload in psychology (Bruijn, Zwaagstra, Weide, 2006). Result was that BVO covered only one of the three components of workload, namely task demands. Individual (subjective) experience of workload and working environment are implicitly or unclear incorporated in BVO.

In relation to task demands there were some important psychological aspects which have major impact on workload, and were not incorporated in BVO (Bruijn, Zwaagstra, Weide, 2006). These aspects are activation, peak demands, long lasting tasks, rule based working versus knowledge based working, and adjustment of task fulfilment.

But BVO also has several positive characteristics. BVO is specific for train dispatching, so train dispatchers recognise their job in BVO. BVO can be used in an analytical way, because it makes clear which task component contributes most to the resulting workload. And BVO not only can be used for evaluating, but also for predicting workload.

The infrastructure management company decided that a new tool should be developed in order to evaluate or predict the component Task demands in the model of workload. But the new tool had to keep the advantages of BVO.

3.2 Development process

Development of Task Weighing™ (Bruijn, Zeilstra, 2007) took place in a highly participative way. The authors facilitated this process and guided the participating train dispatchers through psychological theory. Task Weighing™ is based on BVO, but incorporates modern insights about workload as mentioned in chapter 3.1. These psychological factors were translated into daily tasks and circumstances which were considered to have serious influence on workload.

Necessary adjustments, additions and validations of Task Weighing™ are based on models of the train dispatching job, formulated with train dispatchers. To raise the recognizability of these job models, the models are made with a detailed time line analysis of train dispatching in a certain disturbed situation, at hand. Table 3 shows an example of the weighing of activities within a task component, in this case monitoring of trains.

Task component: Monitoring trains			
Activity	**Description**	**Weighing in Task Weighing™**	**Further notice**
Wtg	Monitoring normal train: a normal train driving according to plan which is being followed without special attention	1	Observation of a train, mostly at the entrance of the area under control, regarding route and special details.
Wtb	Monitoring special train: a special train which is detected and should be followed with special attention (because of for example special cargo or due to delay)	1 = normal cargo and delayed train 2 = special train because of limitation in infrastructure	No other weight per monitoring activity, but higher frequency of monitoring per special train.

Table 3 Weighing of activities within task component Monitoring trains (fragment)

Based on the time line analyses and formulated models of the train dispatching job a translation is made to a calculating formula. The time line analysis made clear which factor or activity was distinctive for a parameter in the formula. Activities directly related to this distinctive factor or activity were incorporated in the weighing of the workload that was originated by distinctive factor or activity.
For example workload due to monitoring of trains is according to the train dispatchers related to the number of trains and to the complexity of the infrastructure in the area under control (table 4).

Calculating formula for the workload due to monitoring trainservice during RUSH HOUR			
	Formula		**Notice**
Workload =	{(1/2 +Mv)*T + 4*Tbt}		Detection of a train
	+ {1*Tbt + 0,1*T}		Interpretation of train status
	+ {0,4*Mv*Tbt}		Anticipation on possible action
	Meaning of parameters		
	T	= number of trains per hour that enters or leaves the area under control	
	Tbt	= number of special trains per hour that enters of leaves the area under control which should be monitored with extra attention	
	Mv	= measure for the complexity of the infrastructure in the area under control	

Table 4 Task Weighing™ Workload calculating formula during rush hour (fragment)

The Task Weighing™ calculating formula is validated by comparison with the time line analysis of all train dispatching activities to perform in a disturbed situation, representative for all railway yards in Holland. As first step in this validation all activities in the time line analysis were classified and weighed with use of the general weighing shown in table 3. This resulted in a number of workload points (without unit) according to the time line analysis. Second step was calculating the number or workload points with a concept of the formula. Third step was evaluation and adjustment of the formula when there were remarkable differences between time line analysis and formula. This process was iterated several times with the participating train dispatchers.

A calculated number of workload points has no meaning if there is not a standard for acceptable workload. This standard also is formulated with the train dispatchers. Table 5 outlines the Task Weighing™ standard for rush hour, e.g. a normal train service during rush hour with commuters and some trains with little delay. The standard for rush hour defines the number of needed train dispatcher for a railway yard. There is also a standard for more heavily disturbed train service and for peak workload during heavily disturbed train service.

Character of train service	Standard in workload points	Notice
Rush hour: Normal train service on busy time of day (commuters) Some trains with little delay	Less than 150	Low workload Light job or possible boredom
	Between 250 and 300	Good workload
	Up to 400	Acceptable workload during several hours (about 3 hours). Overload possible if duration is longer than mentioned number of hours.

Table 5 Task Weighing™ standard for acceptable workload during rush hour

3.2.1 Example: Knowledge based working

Knowledge based working versus rule based working is about puzzling instead of working according to stable rules. In train dispatching puzzling is a distinctive characteristic of the task 'taking safety measures'. Taking safety measures in general is recognized by train dispatchers as a workload raising task. Based on the process of taking safety measures knowledge based working is modelled, see table 6. Typical increments due to knowledge based working are the judgements.

Step in the process	Notice	Task component	General weighing in workload points
Message	- Message about non-standard	Consultation	1 - 6 pts

Step in the process	Notice	Task component	General weighing in workload points
	situation or new situation - Message about deviation of original plan	or Monitoring	
Judgement of the message	Determine the crux of the message. Can be performed simultaneously with receiving the message.	Consultation or Monitoring	Incorporated in the weighing of the message itself
Judgement to determine necessary activities	Judgement on: - Planning consequences - Safety consequences	Judgement	Planning: 2 – 7 pts Safety: 2 -12 pts Depending on complexity of railway yard
Adjustment of plan		Adjustment of plan	3 pts
Communication		Communication	5 - 10 pts
Take safety measures themselves	Control of signals and switches	Control	1 – 8 pts per safety measure. Depending on complexity of railway yard
Double check of right performance of activities in case of safety consequences	Determine whether the performed activities resulted in the desired state of the track.	Judgement	≥ 50% of former judgement to determine necessary activities

Table 6 Process of knowledge based work in train dispatching based on the task ‘Taking safety measures’

Not only the activity ‘taking safety measures’ is an example of knowledge based working, but according to the train dispatchers also ‘control of infrastructure elements (like bridges)’, ‘preparation of maintenance instruction’, ‘safety measures during maintenance’ and ‘assignment of routes’ are.

4. Case study

4.1 Method

Until now Task Weighing™ is used to predict workload for several railway yards in the Netherlands. For complete investigation of workload Task Weighing™ is used together with 2 other instruments: one instrument regarding individual subjective workload (IWS, Integrated Workload Scale, adapted for the Dutch situation, Pickup et al, 2005) and one instrument regarding working environment, e.g. working organisation and working conditions (SKOOP, Bruijn, 2007). IWS is a subjective tool, with which during one hour every five minutes a train dispatcher is asked for his of her subjective workload. During the same hour the performed activities are registered (type of activity, time spent for the activity). IWS has a rating scale for subjective workload from 1 ‘Not demanding’ to 9 ‘Work is too demanding’. SKOOP is a questionnaire about job satisfaction that yearly is used under train dispatchers and other jobs within the infrastructure management company. SKOOP has about 10 questions specific about aspects of workload.

4.1 Scope of investigation

The case concerns a railway yard with a mix of passenger trains and freight trains. Passenger trains are intercity-trains and regional trains. There are 2 train operating companies for passenger trains, with different philosophy on best service to their customers, so with different demands on train dispatching. The railway yard of investigation is last stop for transit abroad. Many freight trains arrive with delay and often there is a switch in train driver.

4.2 Results of investigation of subjective workload with IWS

Based on the IWS-results it can be concluded that the train dispatchers experience the railway yard of investigation as busy. Scores of 5 and 6, that is 'Moderate pressure' and 'Very busy' are most common. There are no indications that train dispatchers experience long lasting overload or underload. But during the period of investigations, 3 weeks, there also was no heavily disturbed train service. With regard to the relation between activities and subjective workload, only communication by phone seems to go together with higher subjective workload.

4.3 Results of investigation of working environment with SKOOP

Results of the SKOOP questionnaire in percentages have no clear meaning. Together with a notice on the results, the percentages get a meaning regarding workload. Special notice on the results for the railway yard of investigation is:

- Freight operators have difficulties in controlling there processes. Regular delays on schedule causes disturbances at the railway yard.
- Train dispatchers for this railway yard are service minded. Freight train drivers can be very directive in their contacts by phone with the train dispatcher.
- There is an increasing the need for maintenance of infrastructure.
- Mistakes in the schedule take a long time to be resolved, although train dispatchers report them regularly to the responsible department.
- Especially during night shifts train dispatchers experience little backup.

4.4 Results of investigation of task demands with Task Weighing™

During rush hour there is a number of more than 300 workload points calculated. When this workload lasts no longer than several hours it is acceptable.

Workload during disturbed train service is very high and can only be done for a short period of time (not longer than 1 hour). In daily practice there is backup for the train dispatcher at the railway yard of investigation, and the calculated number of workload points confirm this practice.

Further investigation of the input data for the workload calculating formula shows that there are a lot of last-minute requests for routes over the railway yard (by phone), a lot of changes of the plan, a lot of hand operated train dispatching and a lot of communications by phone. They all deliver a noticeable contribution to the entire calculated workload.

4.5 Discussion on the results of the case study

Based on the results of investigation it can be concluded that reported subjective workload and calculated workload due to task demands are in agreement with each other during rush hour. The calculated workload during disturbance with Task Weighing™ confirms that during the period of investigation of subjective workload there was no heavy disturbance. The calculation also supports the need for backup procedures during disturbances on the railway yard of investigation.

The investigation of subjective workload shows that communication by phone and higher experienced workload seem to relate to each other. The calculation with Task Weighing™ confirms this relationship because of the relatively high contribution of communication by phone to the calculated workload.

The investigation of working environment points to the service mindedness of the train dispatchers as one of the factors which contributes to a higher workload. This service mindedness to especially freight trains takes the form of acceptance of last-minute requests for routes, changing of the plan, and hand operated train dispatching to keep the trains running. The calculation with Task Weighing™ confirms the higher workload due to this way of train dispatching. Support of train dispatchers in not accepting every request for a route when a train is delayed, and also consultation with freight train operators about their processes and the influence on train service, can help to lower workload of the train dispatchers.

5 Conclusion

The case study shows that the developed calculating formula for predicting workload due to task demands is in agreement with other approaches to investigate workload, e.g. experienced workload and (perception of) working environment. So it can be concluded that the formulated models in the workload calculation of Task Weighing™ are valid for predicting occurring workload in daily practice.
The case study shows how the results of the 3 instruments used for investigation interact with each other and strengthen each other. The 3 instruments together make the discussion about the sensitive issue of workload more objective and point to recognizable solutions for optimizing workload of train dispatchers.

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