D-MOD Dynamic Modelling of Operator Demand

A new simulator module for the evaluation of signaler's demand

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***Abstract*—Estimating signaler demand is critical for ensuring signaling workstations are both feasible to run, and acceptable to staff. While human factors tools exist, they are typically manual, time consuming and rely of the skill of an expert. One solution, explored in this paper, is to use signaling simulators to assist in the estimation of demand.**

Full fidelity signaling simulators are already widely used in the UK. Simulators give the ability to ensure a consistent standard of competency ranging from normal routine tasks to abnormal situations (e.g. faults and failures) monitored by an experienced trainer/assessor. Whilst the original aim of full fidelity simulators was to support training and assessment of signalers, the requirement for an accurate timetable and infrastructure model, and of a realistic workstation Human Machine Interface (HMI), opens up other applications.

The aim of the Dynamic Modelling of Operator Demand (D-MOD) project is to use the Hitachi Information Control System's simulation environment (TREsim signaling simulator) to deliver a workstation evaluation tool. The paper will present how the existing elements of simulator have been expanded and utilized for demand modelling, covering the architecture of D-MOD, the process of selecting and developing demand metrics, and the design of an HMI to deliver a working proof of concept.

Keywords—Simulator; Railway signaler; Training; Workload.

I. INTRODUCTION

There has been a steady transition from distributed, physical control of railway in signal boxes located at several miles from their controlled area. Recently, the appearance of automation has further reduced even more the physical action required by signalers, putting them in a more intense monitoring role. These modifications generated major changes in terms of signaling tasks which evolved from physical to mental tasks, requiring the consideration of an increasing level of information from expanding areas of control. 2015-16 represents a major step in terms of railway transition with the launch of a major project installing new Traffic Management Systems (TMS) in Great Britain.

A. Project objectives

Estimating demand in signaling operations can inform both decisions about current operational practice as well as future technology. Rail industry and Human Factors (HF) professionals have the need to predict the demands on operational staff regulating the traffic. In the case of signaling, this means understanding both how operational conditions now might affect demand, and also the effect of future technologies such as European Traffic Control System (ETCS) and TMS. The main objective of the project will consist of designing and implementing a dynamic model of operator demand, using HICSE's rail simulation platform (TRESIM simulator) for the evaluation of the infrastructure, timetable, and technology development. The impact of ARS and various Human Machine Interfaces (HMIs) on the operator will also be studied.

B. *Scope and Terminology*

Signaling activities include monitoring, regulating, verbal communication, operating infrastructure, using paper timetable, and processing documentation (paperwork) [1]. The goals of workload studies are diverse including the definition of an acceptable level of workload for a workstation, contribution of workload into an accident, work organization and break times, definition of workstation boundaries, evaluation of the impact of additional/change of infrastructure, the impact of a timetable change, ARS inclusion (Automatic Route Setting), and the use of alternative technologies (i.e. VDU – Visual Display Unit). The most significant output is the workload profile providing an indication of the level of operability of the studied workstation. This workload profile is obtained through the evaluation of demands, peaks, spare capacity, conflicting activities, strategies, work organization, and changing aspects of workload (i.e. workload changes between automated/manual operated areas). Considering this context, our project will aim to provide answers to Human Factors professionals by providing inputs to the workload profile associated with a workstation including its infrastructure, timetable and technology, which will consist with an overall and detailed vision of its multiple demand facets.

II. SIGNALER WORKLOAD AND DEMAND TOOLS

Although new signaling systems have reduced the amount of physical tasks and aim to reduce workload through automation and new reliable systems, the signaler has now a role of "monitor or problem solver" [2] which may have its own implications for workload. Since 2000, Network Rail in partnership with the University of Nottingham and various Human Factors consultancies, have developed a number of tools and techniques (available at www.ergotools.co.uk) to evaluate workload using both qualitative and quantitative

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methods. It has become apparent through incidents, and major changes in signaling tasks and technologies that an in depth evaluation by Human Factors professionals is required, as was already the case in the aircraft since many years. Nowadays, workload studies are systematically performed in different contexts, whether pulled by complaints from signalers, accident investigations, audits, new projects inducing infrastructure, timetable and technology changes.

A. Signalers Work and Workload

Main goals of signaler's job consist in guaranteeing safety in the overall workstation, routing trains according to their timetable, and managing various types of events which may occur into the area. In normal scenarios, main signaling activities include the monitoring of train locations, making a parallel with their timetable, train routing made through route setting, tracking records and filling paper procedures in case of events, answering and making phone calls related with the state of infrastructure, adding "reminders" (indicators on track occupied e.g. by a group of workers), anticipating and planning next train movements. In degraded scenarios, other complex signaling activities may be involved which can increase workload more significantly.

Sources of workload can indeed be generated by:

- Intense train monitoring and train delay check;
- The calculation and anticipation of train delays;
- Train regulation and prioritization;
- The number and the nature of communications which are made in parallel of workstation monitoring;
- The monitoring of ongoing events or track activities (e.g. engineering work, accommodation an unplanned train) and the balance with other infrastructure work demands sometimes made in parallel;
- Paperwork to be written in parallel with workstation monitoring even during complex situations;
- Unbalanced peaks of activity (quiet or busy periods);

Even if the introduction of ARS in some workstations automated the majority of routine tasks, signaling work can be complex considering its "multitask" nature. The signaler needs indeed to keep an eye on everything and be able to: switch from different displays, read and interpret different types of information, memorize consistent information during variable duration, monitor multiple trains including future entering ones, take decisions and react to operate efficiently the workstation.

The demands involved by route setting when experiencing train delay or infrastructure events (more commonly called "conflicts"), can be really challenging as the margin for train routing can be very low due to the reduced infrastructure and timetable capacity [3]. This results in low alternate routing options as well as a high level of time pressure in decision making for alternative train routing. In addition, delay and time for a train to complete a path can also be difficult to predict, as inducing lots of parameters such as train speed, train class, line speed, and delays to be related with all other trains sometimes outside of the controlled area.

Conflicts can be solved more or less efficiently with the use of signaling strategies ("signaler's tricks"), which are progressively built with a good knowledge and experience of the workstation which facilitate decision making. Other factors such as level of awareness, attention, memory, motivation and wellbeing will also contribute to the level of complexity of workstation operation.

B. Workload and Demand

Workload is an intuitive notion for humans as related with our feelings and sensibility [4], but the concept lacks an agreed definition. Indeed, many researchers have tried to provide their definition, but none of them has been universally accepted, even the ISO standard definitions have varied through the years [5]. Nowadays, researchers tend to say workload is a combination of demand, resource availability, effort, load, external factors, knowledge, experience, motivation, and wellbeing.

Pickup et al [6] provide a mental workload model introducing demand. In their study, demand was defined by signalers as "the need to maintain awareness of the situation, to process relevant information to make decisions to act". In the resulting model (see Figure 1), demands are created by a dimension called "load" which includes: imposed load (loading factor specific to the task and its context), perceived load (individual's interpretation of load) and internal load (expected level of performance from the user). This vision is particularly interesting for our project, in which the notion of demand seems to be close to Pickup et al's "imposed load". The study of "imposed load" or demand in our case is a first and major step towards the understanding of workload. However, as many researchers suggest, demand itself cannot always explain performance and perceived workload.

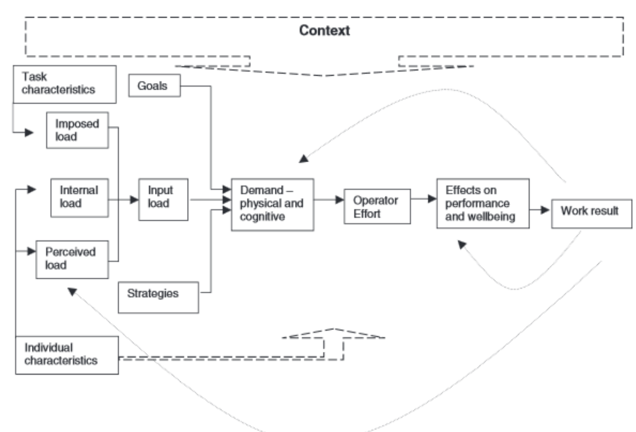

Fig.1 Pickup et al's workload model [5]

C. Current Workload Methods and Tools

A number of demand simulation tools exists and have been applied to many domains such as aircraft, defense, nuclear, automobile, and, since the early 2000s, the railway domain.

Some of the tools include subjective inputs, whereas others concentrate on objective inputs.

Kopardekar et al's [7] used Dynamic Density (DD) metrics to measure and predict air sector complexity. This model based on mathematical variables includes several complexity factors which are defined as the reason that contributes to the difficulty. Their algorithms were tested with a panel in order to compare DD predictions with subjective workload ratings through regression analysis. The results obtained through regression analysis showed coherent results between subjective rating and DD predictions.

Aldrich, [8] introduced a workload computer model in 1989 called the VACP model (Visual, Auditory, Cognitive and Psycho-motoric) applied in defense. This model is based on task analysis and task demands, in which each task demand is detailed in micro entities which are then linked with a resource, time to perform an action/mental process, and complexity or estimated workload ratings provided by experts. This method provides good prediction of workload profile but requires a lot of time dedicated for the task analysis, and provides a granularity for the results which are sometimes not required. Balfe [1] also confirmed this point on view after applying a similar method called Multiple Resource Questionnaire in a signaling study.

In rail several tools have been developed such as TaskWeighing™ [5], OWAT™ (Objective Workload Assessment Technique) [9], ODEC (Operator Demand Evaluation Checklist), PRESTO (Prediction of Operator Time Occupancy), AAT (Activity Analysis Tool), IWS (Integrated Workload Scale) and ASWAT (Adaptive Subjective Workload Tool) (all available at www.ergotools.co.uk).

TaskWeighing™ was used on many projects in the Netherlands, which has a totally different signaling system. This method appears not to be time consuming and works directly with data extracted from signaling machines. It is based on standardized scenarios for a disturbed situation, agreed by Dutch dispatchers. TaskWeighing™ uses a red line for acceptable workload, related to peak load and lasting mental workload. This method can be used in a context of predictive studies, but is based on the way of train dispatching, traffic management and signaling technology in Holland.

OWAT™ provides a deeper analysis of monitoring tasks and can be used in a generic way. OWAT™ makes use of scenarios defined and described in detail (minute-to-minute) by operators. It also shows task conflicts, with which working strategies can be evaluated and improved. Descriptors comprise a red line. Despite OWAT™ provides an accurate overview of monitoring task, this methods has been raised as time consuming, both for operators and for the human factors consultant.

ODEC [10] is a tool designed as a checklist listing quantified infrastructure factors, timetable, and events that can occur in the operated workstation. The output values provide visibility on demand parameters. This method is extensively used within Network Rail and HF consultancies in Great Britain. This tool which is advised to be used as a comparative tool is also/mostly used as a standalone tool. Feedback on this tool is that it is usually one of the first tools applied on a project. Even if this tool looks simplistic, it provides directions and first orientation on projects, but it also gives an idea of where the main demands are currently located in the workstation. ODEC is thus considered from all consultancies as a first good "pass" on projects. One of the problems detected with this method is the relevance of this checklist as technology changes.

AAT method captures signalers' activities in real time providing an overview of his/her occupancy as well as tasks performed in parallel. This tool is one of the most popular and widely applied within human factors studies. However, even if this tool aims to be objective, it has been highlighted that this tool is quite dependent on the observer because of the way it is applied. It is difficult to follow a test alone due to implicit, strategy and decision making applied by a signaler. This is why a SME or another experienced person is necessary to help in the analysis by commenting on the motivations for the signaler's actions as this improves:

- The quality and representativeness of the results with monitoring actions (planning, decision making, prioritization…);
- The overview of signaler's strategy and way to cope;
- The good and quick overview of activities profile.

PRESTO is an objective prediction tool which enables the prediction of signaler's task occupancy as well as a prediction of task conflicts using a timeline analysis. This tool is used for specific scenarios during a specific time of the day; the results are calculated through a timetable analysis made via Railsys. It is perceived as a good, powerful and efficient task analysis/occupancy tool, especially useful in the context of capacity change projects. However, this software is found difficult to use, and relies on the availability of timetable data which are sometimes not accessible. When applied, its major benefit is that it has the potential to predict conflicts between tasks which are one of the main aims of the HF work.

IWS and ASWAT aim to capture signaler's perception of workload using different rating scales. The IWS rating scale focuses on the rating of the perception of the demands and way to cope with them. ASWAT focuses more on the rating of indicators such as time pressure, mental effort and pressure (in a similar manner to the NASA TLX method [11]). These methods are applied worldwide and successful in capturing relevant data, confirming their relevance and consistency. However, Human Factors professional often feel the need to complement these subjective methods with more objective data as the focus on subjective methods only provide subjective inputs and thus be governed by different point on views depending on individuals.

Other researchers [12] have applied other methods using complexity/weighing ratings to quantify signaling effort during regulating context. These methods consisted in describing regulating tasks into different demand factors which can be measured (number of regulating locations, number and types of train movements, number of movements in parallel…) and can be factorized according with complexity rules defined.

D. *Gaps and opportunities*

Signaling work can involve complex cognitive tasks especially during peak periods and while handling events on the infrastructure. In order to evaluate workload, many quantitative tools already exist as we have seen above. Their application depends on the context they have to be associated with. It has been reported by consultancies that tools using red lines seem difficult to implement and tend not to be well accepted by signaling teams. These tools are most of the time associated with KPIs which can have drawbacks as well as advantages. It has also been reported that most of currently applied methods can be time consuming, lack of realistic data (e.g. timetable), and lack of objective quantifications and of multiple representations of demand. Also, many of the objective calculations presented above are static and don't represent variation over time or multiple scenarios. They are also may involve the time of an operator on a running workstation and an SME. These gaps remain to be addressed.

Qualitative input must not be forgotten as users have to be integrated and are central to the study of workload: their experience and feedbacks have to be taken into account at some point in the study. Their good interpretation is also very important. High occupation levels during a short period of time does not always mean that the work in not feasible, but simply means that the signaler will be busy during this short period of time. This is confirmed most of the time with IWS measures where the experience of peak is rare and work is found most of the time to be manageable.

III. TREsim Introduction

Full-fidelity simulators are now regular part of Signaler training as they allow the safe and realistic practice of routine tasks, emergency and traffic delay scenarios. TREsim is the signaling simulator developed by Hitachi Information Control System Europe Ltd., this paragraph will discuss TREsim system architecture and available functionalities end-users are provided.

A. *System Architecture*

TREsim is made of two user interfaces (see Figure 2) each one controlled by a software executable: the trainer interface (Runtime) and the trainee interface (SDS). The trainer interface includes controls to create scenarios (e.g. failures, delays) and check trainee performance. The trainee interface is an exact replicate of its future workstation and user interface, in order to be trained with realistic scenarios.

Both trainer and trainee machine exchange data in real time, enabling the good followed up of actions on both sides. Train movements behave accordingly to the timetable chosen for the simulation, unless an event is introduced by the trainer.

For training purpose trainee and trainer user interface are separated by a wall in order to make an audio separation between them, ensuring the trainee will be unable to detect in advance a change introduced by the trainer (see Figure 3).

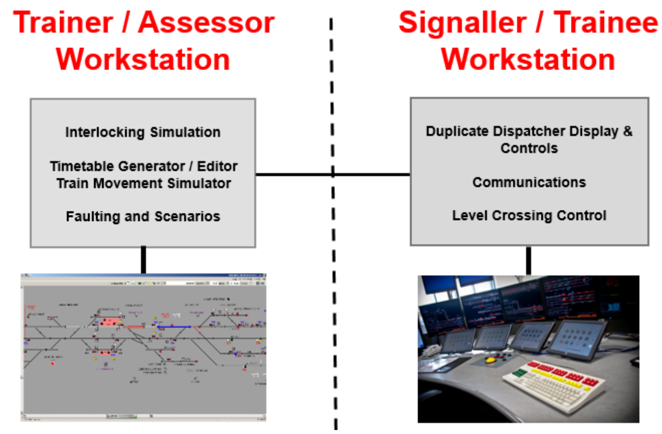

Fig.2 TREsim architecture – trainer & trainee HMIs

Fig.3 TREsim – trainer (left) & trainee (right) HMIs

B. *System Functionalities*

Regarding railway signaling simulators, full fidelity VDU systems require the following minimum capability [13]:

- "A model of the actual interlocking embedded with identical system response times. This ensures when failures are introduced, the display and response the trainee experiences are the exact same way as the real control system.
- The display screens and primary control devices (mouse/tracker ball and keyboard) the trainee uses are exact replicas of the real ones.
- The communication methods the signaler would use are duplicated, i.e. Cab Secure Radio, Signal Post Telephone or GSM-R.
- The actual working timetable for the area covered and Automatic Route Setting (if implemented).
- All track topology (gradients, line speeds, signal sighting) and train performance characteristics (acceleration, braking, traction) are used.
- The environment is as close to the real control center as possible, i.e. the furniture, lighting conditions etc.

- Ability to introduce any infrastructure failures and perturbations such as failures of track circuits, switches, signal lamps, interlocking (whole or modules), train failures, SPAD, non-timetabled freight train etc.
- Ability to initiate record and playback the trainees' performance – both action and communications."

The trainer has also the opportunity to create scripts of a session in advance. Thus, a preset of infrastructure failures or perturbation to be automatically introduced, allowing the trainer to focus on trainee observation and assess other trainees on identical scenarios. Scripts are also used to gradually introduce more difficulty e.g. add more and more failures and perturbations, until the trainee is overloaded. These scripts are really important from a training perspective, as these allow the trainees to recognize their subjective workload limitations, the need to prioritize and when to ask for assistance.

IV. D-MOD Introduction

D-MOD has been integrated as a variant within TREsim simulator. This paragraph will explain how D-MOD was created and which architecture and main functionalities were specified.

A. *D-MOD proof of concept*

The analysis of the human factors simulating tools oriented us toward ODEC which provides an indication of task demand with an acceptable level of granularity for our proof of concept, especially as it gives us a candidate set of proven quantitative parameters to capture for demand measurement. ODEC allows the understanding of the demands associated with the workstation by including infrastructure, timetable and operational rules as required by the project. It also allows the definition of levels which can be compared with other workstations, which can be useful in a context of control center's renovation and workstation extension.

It has been noted from the beginning that ODEC contained mostly static parameters, sometimes too macro to describe a difficulty (amount of resource necessary to complete task demand): our proof of concept consisted also in revisiting some of the ODEC parameters to make such parameters more representative of dynamic traffic patterns.

B. *D-MOD Architecture*

D-MOD reuses existing TREsim architecture and is integrated in the trainer interface as many of its outputs are addressed to observers (see Figure 4). D-MOD is able to provide two types of results: static and dynamic results. Static results are obtained directly from a data extract from the workstation (e.g. number of controlled signals), timetable or TT (e.g. number of trains per hour) and external data provided by the end user (e.g. number of phone calls per day). Dynamic results can be obtained once a session has been recorded, which means that the simulator needs a signaler/SME on the trainee HMI to operate the workstation. Dynamic results are various: number of simulated trains, number of route settings, rolling stock speed variation.

Two levels of software upgrade were suggested:

- Level 0: enables the end-user to study one workstation at a time.
- Level 1: enables the end-user to compare different workstations at a time.

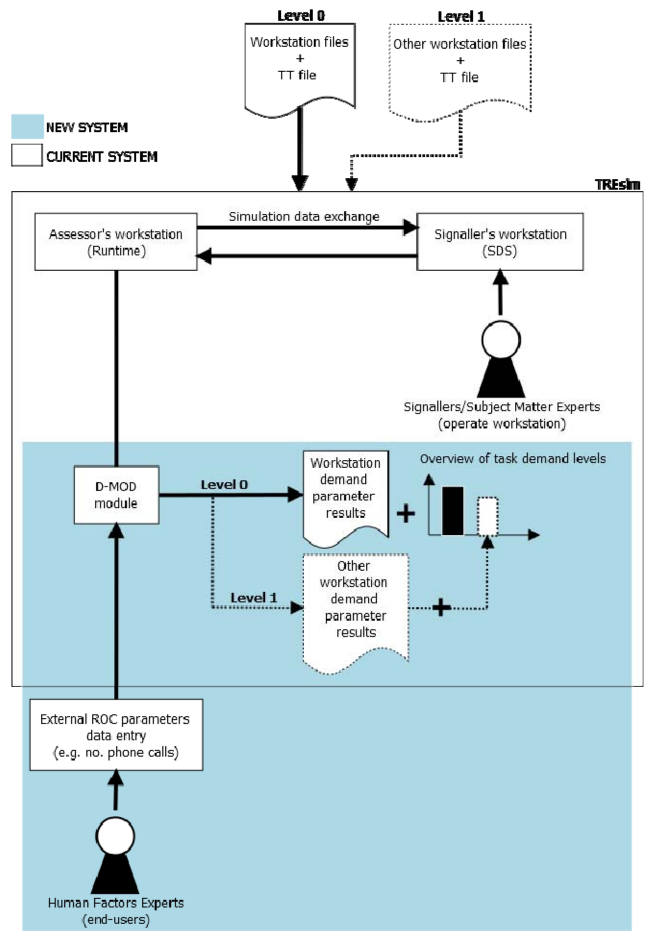

Fig.4 D-MOD Architecture

C. D-MOD Functionalities

D-MOD main functionalities enable the end-user to create,

- New session: end-user can choose a workstation, timetable, area, and run static/dynamic session.
- Load a session: end-user can load a previously saved session and continue static/dynamic session from last saved point.
- Replay a session: sessions recorded are saved as video files to enable the end-user to playback session. Area can still be modified thus enabling the end-user to play with workstation data after session record.

A detailed diagram is introduced below (see Figure 5).

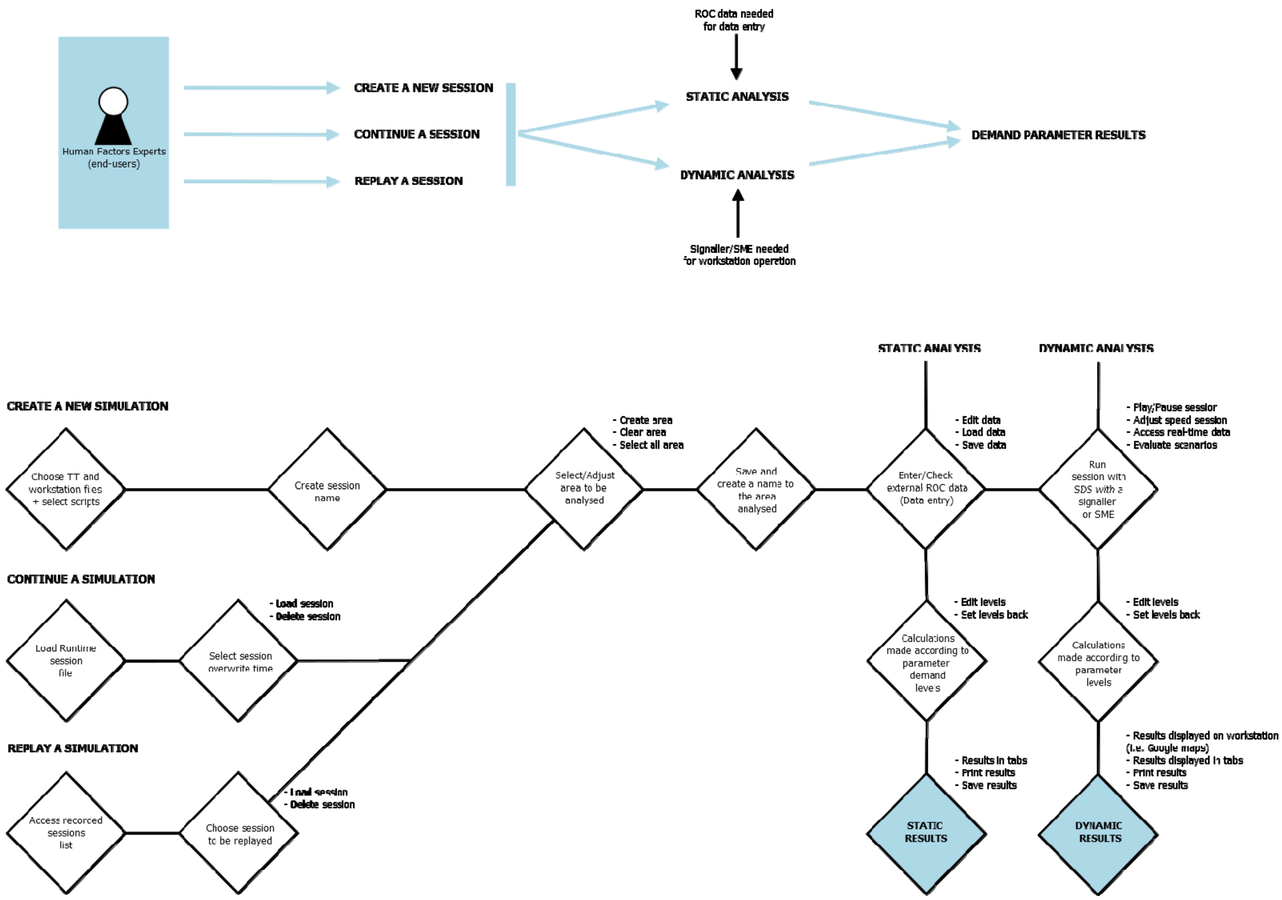

Fig.5 D-MOD Functions

D. D-MOD User Interface

The user interface (see Figure 6) of the new module had to be intuitive, flexible, easily readable and understandable, user error tolerant, but also coherent with the rest of the software. Several functionalities were defined: the saving/replay of the simulation data – the data entry (necessary for external parameters provided by end-users) – the saving of data entry – the display of ODEC results – the display of ODEC or parameters demand levels (high-medium-low limits) – the display of flow results (both number of timetabled trains to be compared with simulated trains) – the display of routes setting results – the display of speed variation results. The display of all these results depends on the area of selection (which defines the area to be analyzed by the software) selected by the end user when starting a session.

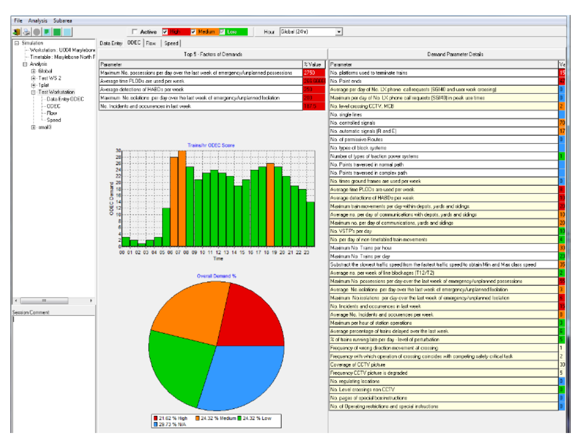

Fig.6 D-MOD User Interface - ODEC tab

Bar charts were chosen to represent dynamic parameter varying in time, pie charts were chosen to display the overall demand results, and tables to display the detailed data calculated by the software. Results were grouped in different tabs: “Data entry” (see Figure 7) which comprise the external data to be entered by the end user and the parameter limits which define the demand levels (high – medium – low) - “ODEC” which displays all ODEC results – “Flow” which displays the number of trains – “Routes” which displays all the route settings – “Speed” which displays speed variation.

Three specific functionalities were created for the module. The two first are related with selection areas: the end-user is able to select an area in order to refine the analysis to be completed: to do this, selection buttons were created in order to allow the end user to draw his own area of selection directly from the workstation sketch. A navigation tree allows the end user to have a visibility on the subareas created: for each subarea ODEC – Flows – Routes have their associated results. The third functionality consist in highlighting in different colors (red - orange – green) the routes/edges included in the selection area depending on their track occupancy to allow the end-user to have visibility on the most frequently routes used in the area.

Other functionalities will be created/updated depending on the progress of the project.

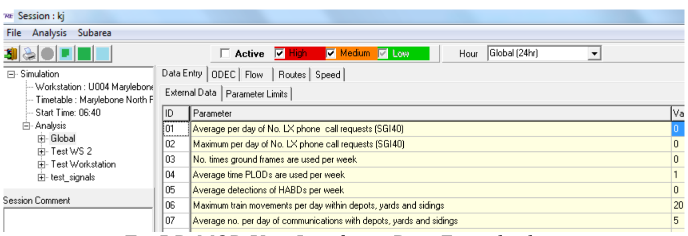

Fig.7 D-MOD User Interface – Data Entry display

E. D-MOD Testing and Results

The development of the first basic module was based on Marylebone North workstation and its 24 hours timetable February 2013. This specific workstation was chosen as it includes ARS, but also various different types of infrastructure present in the railway (sidings, platforms terminating trains…), as well as a timetable comprising a wide panel of train movements (train splits, train joins…). To perform such a test, one assessor and one SME were required: the assessor was in charge to monitor the number of trains in the workstation, the monitoring of specific train movements by managing the timetable, the speed of the simulation via the Runtime interface, as well as D-MOD results update. The SME (20 years of signaling experience) was in charge of the workstation operation on the trainee/SDS interface in order to operate the workstation as in real signaling conditions.

For this first 24h scenario testing, the timetable was run under normal conditions with trains running according to the timetable. In order to simulate a 24 hour timetable, the speed of the simulation was effectively controlled (acceleration more than x10 real time in quiet periods and real time speed during peak times): these time accelerations were facilitated with the use of ARS in the workstation. One 24 hours timetable simulation thus took around 6-8 hours.

The results obtained from Marylebone North testing allowed the overview of various demands and peak demands within the workstation two times during the day. The busiest areas were clearly identified through the colored map and the use of the infrastructure highlighted by the flow and route charts (see Figures 8-9). The number of manual route settings and total number of route setting enable the quantification of manual actions required in the workstation (see Figure 10).

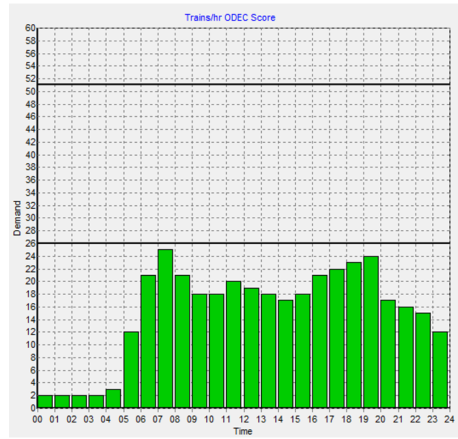

Fig.8 Marylebone hourly timetabled trains – peak time overview

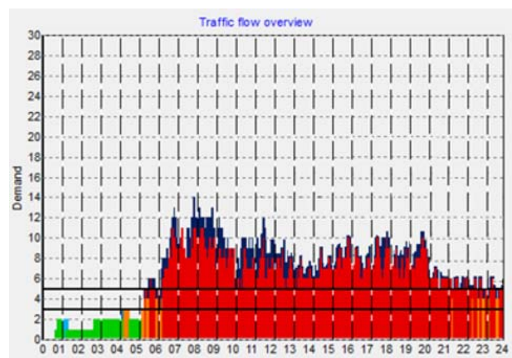

Fig.9 Marylebone timetabled trains (in green/orange/red) compared with simulated trains (trains effectively controlled by the signaler, in blue)

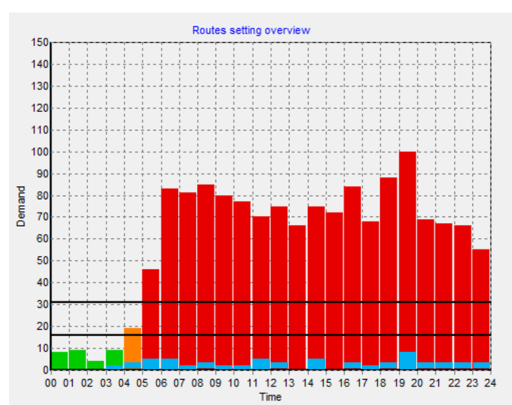

Fig.10 Marylebone route setting overview – total of 5% of manual route setting observed (represented in clear blue), 95% of ARS

V. DISCUSSION

A. Benefits

A first version of D-MOD has been released. This first basic module, designed as a proof of concept allows now:

a) Demand calculations associated with a specific area defined by the end-user: End-users are now able to access quickly to demand result of a specific selection area of the workstation of their choice, allowing them to study the impact on workload these could have on signaler.

b) The semi-automatic calculation of ODEC parameters: Number of signals, routes, timetabled trains, simulated train and many other parameters can be easily calculated through the use of simulator, thus saving time and resource cost to perform an HF study.

c) The checking of the effective application of the timetable allowed by a comparison made by the number of timetabled train and simulated trains operated by a signaler: This comparison can be useful when checking impacts on workstation operation in case of abnormal scenarios, and workstation operation performance. This can also be used to evaluate training, performance curve: the more a signaler is trained, the less difference will be observed between these two figures.

d) More visibility on the number of route settings required in the workstation through charts and tables: Number of route settings can be quite intense especially when testing an ARS workstation. Having an idea of the number of route settings and amount of manual route setting can provide a good visibility on workstation operation in case of abnormal scenarios.

e) More visibility on track occupancy i.e. Google Maps (see Figure 11): A color filter can be applied on each portion of track of workstation, enabling the end-user to have more visibility on how frequent a portion of infrastructure was being used during dynamic testing. This can quickly highlight which area will be more critical in terms of workstation operation in case of degraded signaling conditions.

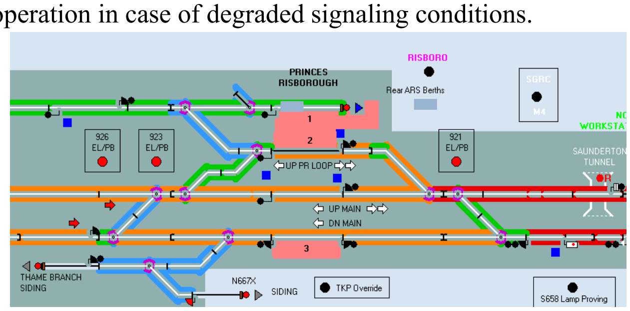

Fig.11 D-MOD Visibility on track occupancy with color filter

f) The simulation of scenarios and the checking of their impacts: As D-MOD is part of TREsim, all track failures or scripts created within TREsim can be used to make specific D-MOD calculations. This allows end-users to compare normal and degraded scenarios results.

g) The testing of ARS influence in the workstation: Still included in TREsim, ARS can be turned on and off and its impacts can be overviewed using D-MOD calculations by making results comparison.

h) An increased level of accuracy due to quantitative data obtained via the use of simulators: Quantitative data provided by the simulator are accurate and objective. Only the demand levels (High-Medium-Low) remains subjective and need to be filled/agreed by the end-user and its project team, depending on which workstation is operated.

i) Visibility on demand results applicable for 24h timetable: Both static and dynamic results can be now provided for a 24h timetable testing in less than a day, which is something brand new in railway HF domain. Moreover, easy readable charts, table are provided to the end- users enabling them a quick and accurate interpretations of workstation results. These charts and tables can easily be reused in project reports part of project deliverables.

j) The replay of signaling actions performed through recorded videos: All signalers actions as well as D-MOD results can be accessed in the replay mode in a video format. As mentioned in previous paragraph, the good interpretation of quantitative data shall be made with a wide understanding of signalers resource and strategies. This replay mode enables the good interpretation of quantitative data by end-users.

B. Challenge

The main difficulty of the project consisted in determining which demand was more important in front to any other one, and with which quantification level (High-Medium-Low ranges) it could be associated with from an objective point on view. Regulating situations are quite difficult to study in terms of the demands it can represent as it all depends on the timetable, infrastructure pattern and subjective signaler strategies. Phone calls which represent also a big part of signaling demand remains to be integrated in the calculations, which will require a lot of thinking on the way they could be simulated.

C. Limitations

One can discuss the quantitative method used for the module: indeed demand reflects an objective value of a potential complexity but maybe lacks of meaning in specific contexts, especially "underload" situations [14], where a phenomenon of dissociation can be experienced. Thus, other methods (experimental, qualitative or physiological) may be useful to complete the module in the future. Some researchers also claim that strategies and the study of workload itself can be much more meaningful for prediction studies [15]. Another fact to be discussed are the demand levels and their associated ranges (High – Medium – Low), which can be very specific to the studied area. Are the experts' inputs sufficient to determine them? Shall these levels remain fixed or dependent to their associated workstation? Finally, several parameters have been integrated into the module: do these parameters, and their formula, provide an accurate overview of the situation? These are the limitations the project is actually dealing with.

D. Future Developments

Future work includes the test of user interface usability and involvement of HF stakeholders from Network Rail (during working group meeting) and the supply chain to develop deployment requirements demand modelling tools such as D-MOD. The release of a new series of requirements and review of the demand levels will enable a second release of the software. New dynamic parameters aim to be created in this future advanced module release and other simulations aim to be made in order to test the accuracy and robustness of the module on different workstations.

Going further into the future, D-MOD is also envisaged as a research tool, able to develop the state of the art in demand and workload tools for signaling and traffic management. Areas of future research include the development of new workload tools, the examination of new forms of automation or HMI, and the understanding of new methods such as physiological measurement.

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