**Promoting passenger behaviour change with provision of**

**occupancy information to help moderate train overcrowding: a**

**cognitive work analysis approach**

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**Abstract**

Passengers’ travel behaviour is one of the significant factors affecting train overcrowding. Train occupancy information has been introduced as a tool to stimulate passengers’ behaviour change to ease in-vehicle crowding. However, there are limitations to this strategy as it often fails to consider other elements in the complex rail system that influence behaviour. This research provides insights to service providers to promote passenger behaviour change by revealing the behavioural constraints in the environment. Cognitive Work Analysis (CWA) was applied to systematically analyse passengers’ behaviour and related constraints in the environment. Specifically, Work Domain Analysis (WDA) and Social Organisation and Cooperation Analysis (SOCA) were conducted and presented in the forms of Abstraction Hierarchy (AH) and Contextual Activity Template (CAT). Results showed that a wide range of informational, navigational and physical support alongside provision of occupancy information could better encourage passengers to select and use less busy carriages and trains. Behaviour change goals are likely to be achieved more effectively when the constraints of the system are better understood.

**Keywords**: Cognitive Work Analysis, Train Crowding, Occupancy Information, Passenger Behaviour Change

# **1. Introduction**

Rail is gaining importance as one of the most sustainable transport modes as society is under pressure to reduce environmental pollution and traffic congestion (Li et al., 2022; Wang et al., 2020; Ross, May and Cockbill, 2020). It is a low-carbon method of transport that can carry high volumes of passengers over long distances. Due to its advantages, authorities are encouraging the shift of passengers from more polluting transport modes to rail, and investing significant sums to ensure rail travel remains attractive to passengers (Department for Transport, 2020; Soltanpour, Mesbah and Habibian, 2020). However, passengers’ travel comfort and satisfaction are negatively influenced by train overcrowding (Hickish, Fletcher and Harrison, 2022; Kumagai, Wakamatsu and Managi, 2020; Haywood, Koning and Monchambert, 2017; Pel, Bel and Pieters, 2014; Passenger Demand Forecasting Council (PDFC), 2017). Insufficient personal space and absence of available seats are common causes of discomfort associated with crowding (Cox, Houdmont and Griffiths, 2006). This close physical proximity to other passengers fosters perceived risks to personal safety, security and privacy, meaning passengers can experience stress, anxiety, and fatigue as well as physical discomfort (Tirachini, Hensher and Rose, 2013; Haywood, Koning and Monchambert, 2017; Pel, Bel and Pieters, 2014). Overcrowding can also lower the attractiveness, perceived monetary value of the service, and ultimately, passengers’ willingness to use the service (Hörcher, Graham and Anderson, 2017). Understanding interventions that could help to reduce overcrowding to improve passengers’ travel experiences and use of rail services is therefore warranted.

In order to moderate train overcrowding, ‘hard’ and ‘soft’ approaches are typically considered. An example of a ‘hard’ approach would be to expand the related infrastructure to resolve a mismatch between supply and demand. An example of a ‘soft’ approach would be to influence passenger behaviour by encouraging them to change when and how they travel by train (Toriumi, Taguchi and Matsumoto, 2014; Network Rail, 2017; Rail Safety and Standards Board (RSSB), 2018). An ideal approach would integrate both the ‘hard’ and ‘soft’ approaches to resolve overcrowding issues and make the best use of rail system capacity (Toriumi, Taguchi and Matsumoto, 2014). However, investments in expanding and implementing rolling stock and track capacity are lengthy and costly (Douglas and Karpouzis, 2006; Cox, Houdmont and Griffiths, 2006). Therefore, this study focuses on supporting changes in passengers’ behaviour, one of the major influencing elements of crowding (RSSB, 2018; Network Rail, 2017).

Crowding influences passengers’ pre-trip and en-route travel decisions and elicits behavioural reactions. For example, passengers change a route to avoid crowding and resultant delays (Kim et al., 2015). They may depart earlier or later or take an alternative line or use a different station. Some passengers tend to wait longer for the next train to be able to get a seat. Others wait near vehicle doors or walk along the platform to board a less busy carriage (Pel, Bel and Pieters, 2014; Schmöcker et al., 2011; PDFC, 2017). The present study focuses on passengers’ choices of carriage and train as these choices neither require a significant amount of amendment in travel plans and arrangements, nor necessarily incur additional costs. Furthermore, these types of behaviour changes or associated intentions can be elicited by providing real-time carriage occupancy information (Zhang et al., 2017; Preston, Pritchard and Waterson, 2019). This study has been motivated by successful trials conducted to stimulate changes in passengers’ behaviour by providing real-time occupancy information. These changes in behaviour are expected to improve the balance of passenger distributions and reduce crowding in vehicles. Railways are a complex socio-technical system that warrant a systems level approach, rather than interventions focused on isolated aspects of the systems, or independent consideration of technical and social systems (Wilson et al., 2007; Stanton and McIlroy, 2012). In line with this systems view, this study explores passengers’ behaviour change within a framework that considers the complex and sociotechnical nature of railways. The investigation will focus on the enhancement of passengers’ comfort and satisfaction as the ultimate purposes of the system under analysis. Stanton et al.’s (2013) study examining modal shift to rail provided inspiration and useful guidance for the present study for the analysis of passenger behaviour change in the rail domain.

## **1.1. Related work**

A number of studies showed that occupancy information can change passengers’ potential or actual behaviour, encouraging them to use less busy services. Specifically, occupancy information could support passengers’ path, train, or carriage selection, as well as distributing passengers along the platform.

In terms of path choice, estimated on-board occupancy information enabled passengers to make informed decisions at origin and stops in simulation settings, reducing on-board crowding and fail-to-board events (Nuzzolo et al., 2016). Similarly, passengers moved to less crowded lines, improving distribution, when real-time crowding information was provided (Drabicki et al., 2017).

For train and carriage selection, participants showed their intention to wait for a less crowded train in response to estimated crowding and seat availability information (Preston, Pritchard and Waterson, 2017). Similar behaviour was also reported in bus use (Kim, Lee and Oh, 2009). When estimated crowding information was given, passengers tended to choose several, rather than a single train (Fukasawa et al., 2012).

In terms of passenger spread, carriage occupancy information positively affected passengers’ intentions to move along the platform and to reposition themselves on the platform to board an emptier carriage. Simulations showed that, passengers tended to wait near the platform entrance when they were not informed. (Ahn et al., 2016). In real-world settings, real-time crowding and seat availability information improved passenger distributions on carriages and reduced in-vehicle crowding (Zhang, Jenelius and Kottenhoff, 2017).

In summary, several studies showed the positive effects of occupancy information as a facilitator of passengers’ behavioural intentions or actual behaviour change that led to alleviation of crowding (Zhang, Jenelius and Kottenhoff, 2017; Nuzzolo et al., 2016; Drabicki et al., 2017). This is unsurprising since informed passengers can make better decisions in terms of “where, when, and how to travel” (Farag and Lyons, 2008). However, those studies omit consideration of current practices for promoting behaviour change. Moreover, they do not provide a theoretical justification of how the occupancy information can be a tool for such behaviour change.

Current practices for passenger behaviour change, such as policing and fines provide negative motivation in the form of a penalty as widely described in transport user studies (Bates, Soole and Watson, 2012; Perry, Erev and Haruvy, 2002; Chen et al., 2020). However, considerable evidence demonstrated that individuals were better motivated by rewards than punishments (Ben-Elia and Ettema, 2011; Geller, 1989). Nevertheless, there are several limitations of rewards. For example, passengers’ decision-making processes involving incentives were also affected by additional factors, such as attitudes, availability of travel information, habitual behaviour and scheduling. Thus, the influence solely elicited from the incentives may be limited. Furthermore, the long-term effects of incentives were questionable as individuals' behaviour induced by the incentives tended to return to the previous level when the incentives were no longer in place (Ben-Elia and Ettema, 2011; Fujii, Gärling, and Kitamura, 2001; Fujii and Kitamura, 2003; Thøgersen and Møller, 2008).

Behaviour change could be better understood with reference to an underlying theoretical background. The most extensively applied theoretical framework to explain travel behaviour is the Theory of Planned Behaviour (TPB) (Ajzen, 1991; Chen and Chao, 2011; Gardner and Abraham, 2008). It posits intention to perform a certain behaviour is determined by attitudes toward the behaviour, subjective norms and perceived behavioural control. Intention, as the central element in the theory, refers to the degree to which an individual is willing to try to conduct the behaviour. Attitude indicates the extent to which an individual has a favourable or unfavourable appraisal of a certain behaviour. Subjective norm as a social factor refers to the perceived social pressure from others to, or not to, conduct a particular behaviour. Perceived behavioural control indicates the perception of the ease or difficulty of conducting a certain behaviour. In general, a person’s intention to perform a behaviour is stronger when both the attitudes and subjective norms relating to the behaviour are more favourable; and the perceived behavioural control is higher (Ajzen, 1991). The TPB has provided theoretical guidance to investigate travel decisions for various studies. For example, individuals’ actual public transport use was explained by the behavioural intentions that were predicted by subjective norms, perceived behavioural control and habits (Fu and Juan, 2017). Private car users’ switching intentions toward public transport were predicted by attitude, perceived behavioural control and subjective norms (Chen and Chao, 2011). In the rail domain, car users’ behavioural intentions to use high-speed rail were predicted by attitude, perceived behavioural control and subjective norms (Borhan, Ibrahim and Miskeen, 2019).

As reviewed, the TPB has provided theoretical guidance to explain transport users’ behaviour highlighting the role of intentions. However, in more recent studies, the focus on individual agency has been weakened. Rather, the importance of constraints on behaviour has been increasingly emphasised whose impacts were overlooked in the theory (Klöckner and Blöbaum, 2010). The criticism seems reasonable because mobility behaviour is not only determined by personal attributes linked to individual mobility (such as sociodemographic and attitudinal factors), but also infrastructural constraints (Hunecke et al., 2007).

Along with the TPB, the concept of habit has drawn considerable attention to understand travel behaviour change (Friman, Maier and Olsson, 2019; Schwanen, Banister and Anable, 2012; Chen and Chao, 2011; Thøgersen and Møller, 2008). Habit is understood as choices which are taken without much contemplation. This contrasts with travel mode choice determined by the deliberate process of reasoned action, explained by the TPB (Chen and Chao, 2011). However, this approach has been criticised as it fails to explain non-automatic situational influences from behavioural constraints (Klöckner and Blöbaum, 2010).

Hence, a comprehensive approach was taken by Klöckner and Blöbaum (2010) to investigate intentional, habitual, normative and situational impacts on travel mode choice concurrently in a structural model. The result verified that travel mode choice was significantly predicted by behavioural intentions and habits, but most of its variance was explained by subjective and objective situational constraints.

Few attempts have been made to identify constraints affecting passengers’ behaviour change in the context of rail use despite the likelihood of these being a major influencing factor (Schwanen, Banister and Anable, 2012; Klöckner and Blöbaum, 2010). The majority of the reviewed literature on the effects of occupancy information presents evidence of passengers’ actual behaviour change or the intentions induced by occupancy information (Zhang, Jenelius and Kottenhoff, 2017; Preston, Pritchard and Waterson, 2019). However, passengers’ stated preferences to wait longer for a less busy train were greater than their revealed preferences. This discrepancy may have resulted from lack of confidence in the accuracy of the estimated occupancy of the arriving train (Significance, 2012 cited in Pel, Bel and Pieters, 2014). Furthermore, the extent of passengers’ actual behaviour change was limited compared to the stated usefulness of occupancy information (Zhang, Jenelius and Kottenhoff, 2017). This reveals a need for enhanced support to enable passengers’ intentions to be better linked to actual behaviour change. Constraints could exist that create barriers to changing their initial travel decisions or behaviours. This could undermine the expected perceived benefits for behaviour change due to cognitive effort for additional planning (Schmitt, Delbosc and Currie, 2019), or physical effort such as walking along the platform.

To ensure *actual* behaviour results from a *willingness* to change behaviour, these constraints warrant further investigation. Nevertheless, there is limited data to inform our understanding about how passengers’ behaviours are shaped by constraints present in the overall system and what constraints may influence behaviour changes (Yu et al., 2015). Moreover, few attempts have hitherto been made to offer comprehensive suggestions alongside provision of occupancy information. A systematic approach is therefore required that considers the systems, occupancy information, passengers’ actions concurrently. This could offer more practical guidance to enhance the likelihood of passengers’ behaviour change to benefit both the passengers and the operator by reducing train overcrowding. In the present study, this will be achieved by applying cognitive work analysis that facilitates holistic investigation into behavioural constraints in this complex socio-technical system (Jenkins et al., 2009).

## **1.2. Cognitive Work Analysis (CWA)**

Cognitive Work Analysis (CWA) was chosen because it enables systematic analysis and modelling of dynamic and complex sociotechnical systems, such as rail systems (Read, Naweed and Salmon, 2019). CWA was originally developed for the usage within the nuclear power industry (Rasmussen, 1986). The method lends itself to identifying constraints on actors’ behaviour shaped by the purposive and physical context. It also facilitates investigation of activities and strategies, as well as the actors’ interaction with the human and non-human components in the system (Jenkins et al., 2009). Due to its benefits, it has been applied in a wide range of research to identify and model various goal-related components considering their means-ends relations (Stanton, Salmon and Rafferty, 2013; Jenkins et al., 2009; Jansson, Olsson and Erlandsson, 2006). They include, military communication planning (Stanton and McIlroy, 2012), variability in road user behaviour (Cornelissen et al., 2013) and in the aviation domain (Stanton, Harris and Starr, 2016). Within the rail industry, it has been used to understand the constraints of modal shift to rail (Stanton et al., 2013) and to the re-design of rail level crossings (Read et al., 2019; Salmon et al., 2016; Read et al., 2016). A number of CWA studies have highlighted the significance to understand behavioural constraints in public transport systems to better support passengers’ behaviour change (Stanton et al., 2013; Read, Salmon and Lenné, 2013). In the present study, CWA will be applied to create insights to promote passengers’ behaviour change facilitated by occupancy information, based on the enriched understanding about constraints in the systems.

CWA can be beneficial for this study for two reasons. First, it can be applied to open systems whose performance can be affected by unpredictable interruptions (Jenkins et al., 2009), such as passenger behaviour and congestion. Second, it is applicable to systems which do not currently exist. This enables to investigate passengers’ potential behaviour on which the present study pays attention (Jenkins et al., 2009).

CWA has five phases: work domain analysis (WDA), control task analysis, strategies analysis, social organisation and cooperation analysis (SOCA) and work competencies analysis. Selection of the CWA phases can be made depending on the nature of the evaluation in question as there is no strict guidance for CWA (Jenkins et al., 2008; Neville et al., 2013). For the present study, WDA and SOCA were applied and presented in the form of Abstraction Hierarchy (AH) and Contextual Activity Template (CAT) respectively.

WDA, the first phase of CWA was selected as it is the most important and commonly used stage. It defines actors’ behavioural constraints imposed by physical and purposive context of the system, and provides a solid basis for subsequent phases including SOCA. WDA gives focus to purposes, functions and physical objects in the system as well as their relationships. The process helps clarify the ‘what, how and why’ of any action that is performed (Stanton et al., 2017). Due to its advantages, WDA has been employed in various studies. Examples include designing interfaces (Burns and Hajdukiewicz, 2004) and decision-aids (Gualtieri et al., 2001), evaluating design proposals (Naikar and Sanderson, 2001), and analysing training systems (Naikar, 1999). The output (AH) systematically outlines constraints including physical elements, the affordances and the functions linked to the system’s ultimate purpose (Vicente, 1999; Salmon et al., 2016). This is particularly useful to investigate behaviour change issues because the AH shows why the actor performs a certain behaviour and what physical objects are involved in the process. This could help highlight constraints that may facilitate or hinder passengers’ choices to board less crowded carriages and trains. In turn, this could provide grounds for the development of more practical approaches to alleviate train overcrowding through passenger behaviour change.

SOCA, the fourth stage of CWA was chosen because it enables analysis of constraints imposed by social and organisational structures in the system by depicting how different functions in the work domain are available for different actors within the system. The diagram (SOCA-CAT) uses different shadings to present where each actor can conduct activities given to them (Stanton et al., 2013). Thus, it helps identify which actors *currently* do what, and what actors *could* potentially do in spatially and temporally separated situations (Vicente, 1999; Salmon et al., 2016).

Applying SOCA-CAT to this study can be useful to understand when and where a specific function could affect passengers’ decision-making. It helps define in what situation different functions could provide an opportunity to promote passengers’ behaviour change. The interpretation could feed into the development of guidance for passenger behaviour change at the right place and time. This is important because some functions are only available at particular stages of a journey or by certain machines or member of staff (Stanton et al., 2013).

The intentions behind passenger travel behaviour are a consequence of passengers’ decisions within situational constraints (Schwanen, Banister and Anable, 2012; Klöckner & Blöbaum, 2010). CWA therefore can bring a richer understanding of how to reduce passenger overcrowding than the TPB, or the concept of habit, in isolation, which may fail to provide sufficient explanation for constraints that may impact passengers’ intentions that lead to behaviour change.

## **1.3. Research aim**

This study aims to identify behavioural constraints by applying CWA to model the UK rail system, through the development of AH and SOCA-CAT. It seeks to generate insights for rail service providers to create a system that better supports passenger behaviour change that could contribute to reducing train overcrowding and enhancing passengers’ satisfaction and comfort. It focuses on the use of occupancy information as a tool to facilitate passenger behaviour change to reduce train overcrowding. The key areas of behaviour change investigated will help passengers choose and board less busy rail services for better distribution in-vehicle. Two types of behaviour change form the focus of this work: 1) to board a less busy carriage by moving along the platform (or within the train once boarded); and 2) to use a less crowded earlier or later train. These were informed by the literature that showed occupancy information significantly changed passengers’ intention or actual behaviour to use a less busy carriage or train (Zhang, Jenelius and Kottenhoff, 2017; Ahn et al., 2016; Preston, Pritchard and Waterson, 2017). Two research questions were established as follows: 1) what constraints are there in the rail system that may influence passengers’ behaviour and carriage/train selection associated with crowded train travel?; and 2) what insights can be developed to facilitate passenger behaviour change based on the systematic analysis of constraints in the system?. The present work is the extended research of the previously published study (Kim, Revell and Preston, 2019). The previous work introduced the AH developed prior to focus group and the work did not include a SOCA-CAT.

# **2. Methodology**

This section describes specific methods used for implementing CWA. A variety of data collection methods were employed in the processes, and the details are outlined in Section 2.2. Review and refinement processes are then described in Section 2.3.

## **2.1. Introduction of AH and SOCA-CAT**

AH is comprised of five conceptual levels explaining functional structures of a system. Each level contains elements (nodes) concerning the characteristics of the levels. The lowest level is the ‘physical objects’ level demonstrating both man-made or natural physical components in the system. The second lowest level is the ‘object-related processes’ level indicating the affordances of the physical objects listed at the lower level. The middle level is the ‘purpose-related functions’ level that links affordances of physical objects at the lower levels to more abstract functional aspects at the upper levels. The second highest level is the ‘values and priority measures’ level explaining how well the system performs to accomplish the functional purpose. The highest level is the ‘functional purpose’ level representing the overall purpose of the system. It expresses why the system exists and it influences all the levels below. Nodes at different levels are connected by means-end links explaining the relationships among nodes in the system (Vicente, 1999). Nodes connected at the adjacent level immediately below explain how the particular function can be achieved. Nodes connected at the adjacent level immediately above describe why certain nodes exist and why the functions are required (Stanton et al., 2013; Stanton, Salmon and Rafferty, 2013; Stanton et al., 2017). Throughout the modelling process, consideration was given to how the fundamental goal of the system could be attained, and what physical elements at lower levels can support higher level functions and values of the system.

SOCA was conducted using contextual activity template (CAT). The template includes constraints and it presents where corresponding functions *can* and typically *do* occur (indicated as dotted lines with balls and whiskers); functions that *could* occur within these constraints but typically do *not* (indicated as dotted lines without balls and whiskers); and functions that are not possible in these situations (indicated as empty cells). It also contains different shades to distinguish between distinct types of users (Stanton et al., 2013).

## **2.2. Data sources**

For the development of the AH, various primary and secondary data sources were used. As the primary data collection methods, participant observation, online user questionnaire and staff interviews were utilised. Data collected from various actors including service providers and users were employed to reduce analyst bias when modelling. Abstract functional aspects of the system, positioned at the higher levels, were primarily identified from the literature on train crowding and the impact on passengers’ behaviour. Physical aspects of the system and their functions placed at the lower levels were chiefly informed from the primary sources. For the development of the SOCA-CAT, relevant data from the AH (key object-related processes) were utilised as work functions.

The studies conducted for the primary data collection were approved by the University of Southampton Ethics Committee. Approval numbers are as follows: questionnaire study (41385); interview studies (46020).

#### **Participant observation**

Data from two participant observation studies were used to identify nodes and means-end links at lower levels of AH (physical objects, object-related processes, and purpose-related functions). They were conducted to investigate constraints by being immersed in the actual system environment. The sites were London Victoria, Gatwick Airport, and Brighton stations and trains operating between the stations. The locations were deemed worthy of investigation due to their position on one of the major routes leading to London. The level of crowding on trains on the route can be particularly problematic in the morning peak period (Department for Transport, 2018). Facilities as well as behaviours of passengers and staff were observed in the stations, passages, and on the platforms and trains. Physical components, their roles and interactions with passengers were the focus of attention. Observation notes, photographs and videos were taken, and they were reviewed in the AH establishment process.

#### **Online user questionnaire**

Data from an online user questionnaire were used to verify the potential effects of occupancy information on behaviour change and to identify additional elements relevant to the decision-making process by passengers.

The form contained questions about the perceived value of seated travel, and the factors that mattered most when selecting a carriage to board (amongst train crowding, platform crowding, location of exit or entrance, luggage rack and other). It also included questions concerning the willingness to move along the platform to board a less busy carriage according to carriage occupancy information and the intention to do so with heavy luggage. The information was visualised with train carriages as boxes with occupancy graded by colour: red (full), mostly filled with grey (busy), partially filled with grey (quiet) and white (empty). Lastly, an open-ended question about what additional information could be useful to get to a less crowded carriage along with the occupancy information was asked. Although the main objective of the questionnaire was not for performing CWA, the questionnaire data were relevant and beneficial to build the AH as a ‘secondary source’. The responses informed nodes and means-end links at intermediate levels (object-related processes, purpose-related functions, and values and priority measures).

The questionnaire form was distributed on various online platforms including staff news on the University’s intranet, the University’s Student Communications Facebook page and also by an official invitation email to staff members based at the Boldrewood Innovation Campus of the University. Furthermore, UK rail user groups affiliated to Railfuture (an independent organisation campaigning for better railway) were approached and asked to distribute the form. Three out of 27 contacted groups posted the questionnaire on their websites or twitter pages.

Prior to the questionnaire administration, the participants were requested to review information about the questionnaire. They were then asked to complete a consent form as an expression of willingness to participate in the study.

In total, 119 respondents (70 males, 47 females and 2 missing responses) participated in the questionnaire study. The sample consisted of a higher proportion of male respondents. This may reflect the fact that more rail trips were conducted by males than females under 60 years (DfT, 2017). Furthermore, more surface train trips were undertaken by males than females per year (DfT, 2018). Age distribution was shown as follows: 18-24 (N=23); 25-34 (N=49); 35-44 (N=25); 45-54 (N=9); 55-64 (N=8); 65-74 (N=4); missing (N=1). The participants’ general purposes of rail travel were leisure (N=57); business (N=52); other (N=8); and missing (N=2).

With regards to data analysis, frequencies were computed to identify trends in responses to multiple choice questions. For the open-ended responses, the collected data were read thoroughly and coded according to the corresponding levels in the AH.

#### **Railway staff interview**

The railway staff interview data were used to gain an understanding about potential effects of occupancy information on performance measures and the resulting benefits of better management of crowded situations to passengers. Whilst the primary purpose of this interview was not designed for CWA construction, the insights relating to how the staff managed overcrowding and the type of information they required were highly relevant to different levels of the AH under development. As such the interview transcripts were used in the AH construction similarly to a ‘secondary source’. This data set ensured the AH reflects the constraints and affordances relevant to a range of rail staff. The data were used to determine nodes and means-ends links through the AH.

In total, 10 rail staff (9 males and 1 female) from Gatwick Express were interviewed to understand; 1) how different staff roles were responsible for reducing passenger overcrowding; 2) to determine how occupancy information could help in their role and; 3) to capture the helpful features and opportunities to improve a publicly available website used by staff. Staff roles comprised 3 on board supervisors, 3 platform staff, 1 on-board depot manager, 1 area station manager, 1 customer service manager and one customer experience and line manager. Staff ages ranged from 26 to 48 years with a mean age of 34.9.

The participants were asked to sign a consent form and the interview was audio recorded. After being asked to describe their roles and their responsibilities each participant was asked the following questions by a Human Factors Analyst (the second author):

* How does your role relate to managing passenger crowding on carriages and platforms?
* How important is loading information to your role?
* Do you currently get information on passenger loading? If so, how?
* How do you use information on passenger loading in your role?

The participant was then introduced to the website <https://www.opentraintimes.com/> on a laptop and talked through its purpose by the developer and the following questions were asked by a Human Factors Analyst (the second author):

* Have you used this system before?
* When [would you / do you] use this system?
* How useful is this system for your role? Why?
* What specific features are useful to your role?
* [If you have used this system before] What device do you use it on? Why?
* Is there anything else you would like to see on this system?
* If we added [suggested feature] on this system, where would you like to see it?

The audio-recordings of the full interviews were transcribed. The full transcriptions were then coded according to which level of an AH they related. The coded data were used to construct the AH described in the following section.

## **2.3. Development of AH and SOCA-CAT**

This section discusses AH and SOCA-CAT development processes performed using the data described in the previous section. The AH informed the following phase, SOCA. Hence, the scope defined for the AH was consistently applied to the SOCA-CAT.

### **2.3.1. AH development process**

Vicente’s (1999) development of AH representation was considered in this process.

#### **Identification of analysis scope**

The aim of the study was to define constraints on passengers’ behaviour change associated with carriage/train selection by modelling a system based on the UK rail domain. The scope on the analysis explored the management of crowding on rail transport through ‘soft’ measures, with a focus on passenger comfort through access to seated travel. The system aspects relevant to passenger distribution across carriages and train services were therefore considered. The focus at the physical objects level and their functions considered not only passengers’ comfort and satisfaction, but also aids to decision making about carriage and train selection. The boundaries of analysis were established with respect of the system as experienced by passengers. For instance, railway track, power supply system, signals and gantries were not considered as physical objects (Stanton et al., 2013). This passenger experience perspective was also applied to identify functional purposes. They were established as satisfaction and comfort because they were major factors affected by passengers’ travel experience in crowded conditions (Haywood, Koning and Monchambert, 2017). In addition, they were both related to passengers’ travel behaviour change (Abou-Zeid et al., 2012). Comfortable transport was one of the functional purposes concerned with passengers’ behaviour change to use rail service in the AH introduced in Stanton et al.’s (2013) study. Understandably, the present study overlaps with the perspective undertaken by their study. Hence, a number of nodes linked to comfortable transport in their study were considered in the AH of the present study. The AH developed in this study will be a representation of optimum rail system which would facilitate passengers’ behaviour change through occupancy information. Turn up and go services were mainly covered, but seat reservation was also considered as a method for securing a seat.

#### **Creating nodes between levels**

Nodes at the two top and the two bottom levels were created first because this can be more practical and easier than top-down approach (Vicente, 1999; Naikar, 2005). Then, nodes at the intermediate level bridging between the upper and lower levels were established. During the process, nodes at the same level were established in the same modelling language by using triggers for consistency within a level, and distinctions among levels (Jenkins et al., 2009). “Why, what, how questions” were recursively used to verify means-end links. Multiple revisions were made because WDA is a highly iterative process (Vicente, 1999, p.171).

#### **Review and refinement processes**

Two interviews with subject matter experts (SMEs) in the rail domain, and a focus group with frequent rail users were conducted to review the AH and reduce unconscious analyst bias. Both service providers and users participated in the review processes because they represented important actors in the system, thus perspectives of both parties were of value. The focus of the review was to verify the contents being relevant to the purpose and the domain.

##### **Subject Matter Expert (SME) interviews**

Each SME took part in one interview session that consisted of two parts. The first SME was an area station manager working for one of the UK rail operators with over 18 years expertise in customer service in the rail and airline industries. They had experience managing a team of on-board supervisors and developing staff training programmes. They were also in charge of allocation of staff within the station. They offered knowledge about customer experience management and rail passenger behaviour from a service supplier’s perspective. The second SME was a rail information systems professional with over 20 years’ experience in consultancy, data analysis and software services. They supplied knowledge considering the current and possible rail information system to support passengers’ behaviour change.

Participants were asked to review information about the interview and sign a consent form. Each interview was audio-recorded, and the duration of each interview was approximately 2 hours. They were given explanation about the purpose of the study and CWA. During the first part of the review, they were presented with the pre-defined AH by the first and second authors in which all the nodes and means-end links were included. The scope of the analysis was explained and the nodes at each of the five levels, and means end links between nodes at different levels, were reviewed in turn. In part two of the review, the SME’s were provided with sections of the AH that contained nodes linked to passengers’ behaviour change through carriage and train selection. They were asked to review the nodes and means-end links carefully taking account of why the nodes at lower levels were required, and how the nodes at higher levels could be achieved. They were given the opportunity to remove or add nodes and means-end links in the AH and provide explanations for their decisions.

##### **Focus group**

A focus group was conducted with five rail users for the AH review. The participants comprised of four males and one female aged between 27 and 55 with a mean age of 39.4. They included four staff members and one student from the University of Southampton. They were frequent rail travellers who made more than one rail journey per week. Frequent users were recruited as they are more likely to have relevant knowledge about where they need to wait to board a required carriage. Without the knowledge, passengers tended to wait near platform entrance (Kim et al., 2014), or wait in the middle of the platform (Rail Safety and Standards Board, 2018). The participants reported that they preferred to sit than stand while travelling on the train. Users who preferred to sit were recruited because the preference for sitting could be a strong facilitator of behaviour change (Schmöcker et al., 2011). The study was approved by the University’s Ethics Committee (approval number: 46870).

In the focus group, the participants were informed about the purpose of the research and the format of the session verbally as well as by reading a participant information form. After being given an opportunity to ask any clarifying questions, they were then asked to sign a consent form. The duration was approximately 2 hours. They were given information about CWA, each level of the AH, and the construction process. Unlike the SME review process, the focus group participants could suggest elements at each level after being presented with the functional purposes in the initial AH. Different review processes were taken because it was important for the focus group participants to be able to express their opinions without being biased by the pre-defined AH. Therefore, giving questions in an unbiased way was important as they tended to provide opinions based on their personal experience (Basch, 1987). Conversely, the SMEs had specialist understanding in the field, thus they were thought to be able to examine nodes and means-end links in the pre-defined AH based on their professional knowledge and would be less subject to bias. In addition, different processes were taken to facilitate more active interactions amongst the participants in the focus group. The second author with extensive experience in performing CWA provided guidance on identification and position of nodes and means-end links.

The final version of the AH reflected the input of both the SMEs and the focus group participants. Before finalising the AH, a model refinement process was executed. For instance, the initial AH was compared with the AH reviewed by the SMEs and focus group participants. Nodes and means-end links established either in the SME interviews or focus group were retained or added. Nodes and means-end links which were not agreed, for example those with weak ‘how’ and ‘why’ associations either in the SME interviews or focus group, were removed.

### **2.3.2. SOCA-CAT development process**

To develop the SOCA-CAT, situations were defined according to places, such as origin (home or workplace), en-route to station, station, platform and train on the horizontal axis. In this analysis, the last situation, train, did not include changing or alighting from trains. It only focused on the situation in which passengers board and walk along the carriages to get a seat. Constraints were identified from the AH as CWA outputs from other stages can be used for this analysis (Stanton et al., 2013; Read et al., 2015). Work functions were presented on the vertical axis. A number of object-related processes were added that were linked to carriage and train selection at the purpose-related functions level. Only key object-related processes were selected based on the representativeness. For example, ‘support navigation’ was included as a representative node of ‘locating own position on the platform’ and ‘providing landmark on the platform’. For the analysis, the emphasis was placed on when and where the functions can be used by passengers to actively decide to change their behaviour rather than when and where those functions are performed by passengers. A similar approach was taken in the Stanton et al.’s (2013) CWA study.

The SOCA-CAT was shaded with respect to two actor groups: time-restricted users who could not change travel date and time, and time-flexible users who could adjust travel date or time, as travellers’ train and carriage selection can be influenced by their flexibility in their schedule (Preston, Pritchard and Waterson. 2017). For instance, airport passengers who have a flight to catch cannot wait for an empty train arriving at the destination later than their flight. Passengers who are short of time may not walk along the platform to board an empty carriage, or they may not want to board an empty carriage further away from the exit if they need to egress quickly at destination station.

#### **Review and refinement processes**

One SME interview was carried out for the SOCA-CAT review. In addition, the focus group held for the AH review had an additional session for the SOCA-CAT review that informed the refinement process. The reviews were performed to achieve unbiased analysis by incorporating SME’s and users’ input. They were used to verify the effects of the work functions in light of current industry practices as well as actual usage. The review processes included confirming or redefining the areas in which pre-identified work functions could occur, or typically occur considering the activities of different user types.

##### **Subject Matter Expert (SME) interview**

One SME participated in an online interview session. They were a senior researcher in the domain of rail and transport working in both academia and consultancy for over 20 years. They were specialised in planning and designing transport systems primarily in railway operation. They were an active rail user, thus they could provide insights about the effects of work functions from a user’s perspective as well.

The interviewee was asked to review participant information and sign a consent form prior to the session. The interview was video recorded, with a duration of approximately 1.5 hours. At the beginning of the session, an explanation about the study purpose and CWA was provided. This was followed by an introduction to the SOCA-CAT, its components (work functions and situations), and the passenger types. The pre-defined SOCA-CAT was then presented. The SME was asked to review when and where the defined work functions typically or possibly occur; and when and where the functions could impact, or inform users’ decision making linked to behaviour change. The process involved reviewing positions of dotted lines, balls with whiskers and shades. They were offered opportunities to modify the components by extending, shortening or moving them after providing clear reasoning.

##### **Focus group**

In the session, the participants were presented with the pre-defined SOCA-CAT. Then they were asked to review when and where the functions are usually performed, or could facilitate their journey planning or implementation. They also discussed the situations in which those functions do not occur. At the end of the process, work situations in which work functions could occur or typically do occur were confirmed. The difference in impact for time-restricted and time-flexible passengers was considered.

The final version of the AH and SOCA-CAT were used for a systematic analysis of constraints in the following section. Interpretations of the AH provided a foundation to develop insights on how to design a rail system which facilitates changes in passengers’ behaviour. Focus was placed on the constraints that may affect passengers’ selection to board a less crowded carriage and train. For example, nodes at the lower levels (object-related processes and physical objects levels) connected to the defined passengers’ behaviours by means-end links, were considered affordances for behaviour change. These offered a basis to develop insights on *how* to support the selected passengers’ behaviour changes. Furthermore, nodes at the higher levels (values and priority measures and functional purpose levels) connected to the defined behaviours by means-end links were considered as insights into *why* passengers would perform the behaviours. The SOCA-CAT was utilised for methodical analysis of usage and the influences of a range of key constraints on passengers’ decision making in journey situations. The interpretations enriched the insights generated by the AH with respect to when and where appropriate support could be implemented to maximise behaviour change.

# **3. Results**

In this section, the final version of the AH and the SOCA-CAT will be introduced. For the AH, descriptions will be presented for each level with justifications for identification of nodes. Numbers were given for the five levels, from top to bottom (from 1 to 5) for easier understanding. Nodes at each level were numbered from left to right (from 1 up to the maximum number) at each level with the level number in front (e.g. 1-1: level 1 node 1, 2-1: level 2 node 1). All the identified nodes at functional purpose level (level 1) and values and priority measures level (level 2) are presented in the AH. Relevant nodes were put into groups and the groups are presented at lower levels: purpose-related functions (level 3), object-related processes (level 4) and physical objects (level 5) in the AH due to space limitations (see Figure 1). Passenger behaviour change indicated at purpose-related functions level (level 3, node 5: representing behaviour change linked to carriage, train and mode selection) was the focus of analysis for insight generation described in the following section. Nodes connected with the behaviour changes at lower levels (levels 4 and 5) by means-end links helped account for how they can be achieved. Additionally, those connected with the behaviour changes at higher levels (levels 1 and 2) were used to explain why the functions need to be accomplished. For the SOCA-CAT, descriptions of the identified constraints will be supplied at the end of this section, focusing on user types and situations.

|  |  |
| --- | --- |
| **Level1**  Functional purpose |  |
| **Level 2**  Values & priority measures |
| **Level 3** Purpose-related functions |
| **Level 4** Object-related processes |
| **Level 5** Physical objects |

**Figure 1. Abstraction Hierarchy (Simplified)**

|  |  |  |  |
| --- | --- | --- | --- |
| 2 | Potential behaviour changes | 2 | Nodes linked to the behaviour changes |
| 2 | Nodes not directly linked to the behaviour changes | | |

*Note*: All the nodes identified in AH are demonstrated in Appendix A

## **3.1. Functional purpose (Level 1)**

The ultimate purpose of the system under investigation in relation to reduction of overcrowding was defined as to enhance passengers’ on-board comfort and satisfaction through seated rail travel. Crowding in public transport showed a negative association with satisfaction with the use of the service (Haywood, Koning and Monchambert, 2017). Understandably, train overcrowding makes the service less appealing and subsequently less attractive to passengers (Lyons, Jain and Weir, 2016; Haywood, Koning and Monchambert, 2017). Insufficient room for sitting and standing due to high passenger density can lead to passenger discomfort and stress (PDFC, 2017; Haywood, Koning and Monchambert, 2017; Cox, Houdmont and Griffiths, 2006). Therefore, improvement of passenger experience can be expected from reduction of train overcrowding. In terms of passengers’ valuation of seat availability, most passengers preferred to sit than to stand. They would choose to sit if many seats were available although some passengers were happy to stand while travelling for a short time. Some passengers occasionally travelled backwards to avoid crowding and to secure a seat during the Underground travel (Hörcher, Graham and Anderson, 2017). Thus, focus was given to getting a seat as a contributing factor to comfort and satisfaction with train travel. The construction of Figure 1 depicts the identified purposes as fulfilled through the connected nodes at the level below (Level 2).

## **3.2. Values and priority measures (Level 2)**

Nodes at this level were established by reviewed literature regarding influential factors of comfort and satisfaction associated with travelling in crowded trains. Each node is explained from left to right (see Figure 1). Node 2-1, ‘stress-relief’, represented the need to relieve stress induced by insufficient room resulting from passenger density on crowded trains (Evans and Wener, 2007). More focus was placed upon train crowding as passengers’ perception generated from “interplay of cognitive, social and environmental factors” in the environment. It was associated with passengers’ subjective experience of exhaustion and stress on the train, rather than density as “objective physical characteristics” (Cox, Houdmont and Griffiths, 2006; Mahudin, Cox and Griffiths, 2012). Node 2-2, ‘safety and security’ gained importance because perceived risk may be induced by travelling in crowded trains (Cox, Houdmont and Griffiths, 2006; Katz and Rahman, 2010; Cheng, 2010). Crowding was one of the antecedents of perceived risk of personal safety against potential crimes and accidents (Cullen, 2001 cited in Cox, Houdmont and Griffiths, 2006). Not surprisingly, passengers tended to perceive the environment less safe and less comfortable when travelling with fellow passengers in crowded conditions (Katz and Rahman, 2010). Node 2-3, ‘value for money from seated journey’ could be understood as the degree of value assessed by passengers compared to the money spent on purchase of the ticket. Standing when travelling on a crowded train was perceived to be of reduced value (Douglas and Karpouzis, 2006). Node 2-4, ‘timeliness’ associated with train overcrowding needed to be viewed at the network level. Passenger density was one of the elements which determined boarding and alighting times connected to train dwell time (Transportation Research Board, 2003; Seriani and Fernandez, 2015). Delayed boarding and alighting were observed due to higher passenger density in the middle of the platform or near platform entrances at Gatwick Airport Station. Hence, more balanced distribution of passengers among carriages and on the platform could lead to reductions of dwell time, and in turn improvement of timeliness and punctuality of train services. Ultimately, this could contribute to on-time performance which was linked to passenger satisfaction with public transport services (Mouwen, 2015). Node 2-5, ‘productivity’ was chosen because productive use of travel time showed a positive association with higher travel satisfaction (Wang and Loo, 2019). High passenger density could negatively affect on-board productivity and in-vehicle utility (Cats, West and Eliasson, 2016; Haywood, Koning and Monchambert, 2017; Cox, Houdmont and Griffiths, 2006). Node 2-6, ‘sense of control’, could be interpreted as individuals’ belief that they have the power to influence decision making to achieve their situational desires (Rodin, Schooler and Schaie, 2013). Maintaining a sense of control was important because it could help alleviate passengers’ stress and subsequent negative effects in highly dense environment. Further, it was associated with travel comfort. Passengers who lack the sense of control tended to perceive a high-density environment as more crowded and stressful. Options to choose or the quality of the options were also related to perceived control (Cox, Houdmont and Griffiths, 2006; Mohammadi, Amador-Jimenez and Nasiri, 2020). Node 2-7, ‘personal space (optimal loading)’ could be increased by reduced crowding. Higher density represented insufficient personal space which increased the possibility to have unwanted social and physical interactions with fellow passengers (Evans and Wener, 2007). Node 2-8, ‘seats available’ were included because being able to get a seat was considered in passengers’ choice of route and departure time. For instance, passengers were willing to wait longer to take the next train to secure a seat rather than to board the train departed first. Consequently, informing passengers about seat availability at boarding points could influence their decisions (Schmöcker et al., 2011). Node 2-9, ‘privacy’ needed attention because it was a contributing factor for satisfaction with public transport use (Imam, 2014). Rail passengers often felt invasion of privacy in crowded conditions, and understandably privacy was highly valued by private mode users (Wardman and Whelan, 2011; Tirachini, Hensher and Rose, 2013). Deprivation of privacy was mostly connected to sitting close to other passengers (MVA Consultancy, 2008; Pel, Bel and Pieters, 2014).

## **3.3. Purpose-related functions (Level 3)**

Nodes at this level were considered enablers for the values established at the level above (level 2). Relevant nodes were grouped and only the groups are presented in Figure 1. Insights were chiefly obtained from interviews with staff and participant observations. Throughout the process for defining purpose-related functions, ‘what do object-related processes identified at the level below influence or benefit users?’, and ‘how can values and priority measures defined at the level above be achieved?’ were applied as prompts. Once the nodes were defined, supporting literature was then consulted to strengthen the decision. Key nodes were proposed as follows. Node 3-1, ‘respond to risks and hazards’ represented a need to provide assistance for passengers to minimise the probability of an accident such as slips, falls, risk of injury or train accident while boarding, alighting, or waiting (RSSB, 2013). Node 3-2, ‘access discounts/offers’ such as special offers and cheaper tickets was useful to facilitate the use of off-peak trips to help distribute excessive demand for peak time travel (National Rail, 2022). Node 3-3, ‘weigh up opportunity cost’ could be part of journey planning. For instance, passengers attempted to make an optimal travel decision considering pursuit of travel time and travel comfort, such as standing during a quicker journey or taking a slower seated journey; or using an alternative route or mode (Wardman and Whelan, 2011). Node 3-4, ‘use information’ was considered essential for passengers to fulfil their seated journey goal (Interaction Design Foundation, 2022). Types of information embraced not only information about occupancy, but also routes, disruptions, cancellation, departure, and estimated arrival times. Node 3-5, ‘behaviour change’ could occur as a reaction to overcrowding. Examples included: taking a less busy alternative mode (Cox, Houdmont and Griffiths, 2006; Tirachini et al., 2017); an earlier or later train by leaving earlier or waiting longer (Preston, Pritchard and Waterson, 2017); an emptier carriage by walking on the platform (Ahn et al., 2016); and by moving along the train. Node 3-6, ‘secure a seat’ was one of the important factors considered by passengers to enhance journey comfort. This could be achieved by reserving seats whenever possible or receiving assistance from staff to find and reach available seats more easily if a turn up and go service was in place. Node 3-7, ‘maintain passenger flow’ on the platform and the train represented the necessity to enable passengers to easily enter, exit and walk along the platform or the train. This was needed especially for the areas where passenger density was often high, such as entrances and exits, and middle sections of the platform (Seriani and Fernandez, 2015). Node 3-8, ‘assist passengers’ was required for those who may need special travel requirements due to vulnerable physical conditions, or who travel with heavy luggage or company.

## **3.4. Object-related processes (Level 4)**

Nodes at this level clarify how the purpose-related functions (Level 3) could be achieved with the help of physical objects at the bottom level. To define pertinent components, insights were sought from staff interview transcripts, observation notes and online questionnaire data. Throughout the process, ‘what do physical elements in the rail systems function and afford?’ was consistently used as a prompt. Particular attention was given to passengers’ interactions with physical aspects in the system. Key nodes were established as follows. Node 4-1, ‘provide and communicate information’ was proposed. Examples of information included general information about public transport or train travel such as routes, departures, arrivals, disruptions, train formation and service occupancy. Node 4-2, ‘help estimate seat availability’ was suggested to facilitate passengers’ activities to estimate where they can find free seats more easily. Node 4-3, ‘support navigation’ indicated the necessity to help passengers to locate themselves in the station or on the platform in relation to the required carriage. Node 4-4, to ‘enable financial transaction’ represented the availability to buy and amend travel tickets using available devices and facilities. Node 4-5, ‘provide offerings and discounts’ was added. Node 4-6, ‘mitigate platform density’ highlighted the need to reduce waiting passenger density near certain areas of platform that could hinder passenger flow. Node 4-7, ‘support psychological needs’ addressed the significance to assist passengers to feel comfortable and relaxed when waiting and moving on the platform. Node 4-8, ‘support physiological needs’ described the roles of physical or human resources to aid passengers to wait comfortably, move, handle luggage easily, or to protect themselves from harsh weather.

## **3.5. Physical object (Level 5)**

Nodes at this level elucidated physical objects in the systems that afforded the processes at the level above (level 4). The nodes were constructed by reviewing observation notes, footages, interview transcripts and online resources (National Rail, 2022a). Node 5-1, ‘information systems’ contained information displays installed in the station and train, information desks, ticket offices, ticket gates and passengers’ devices, such as mobile phones and tablets. Node 5-2, ‘media of information’ included websites, adverts, signage, printed materials and service announcements. Node 5-3, ‘physical facilities and environments’ indicated stairs, escalators, lifts, waiting rooms, lightings, layout and structures of stations and trains. Node 5-4, ‘personnel’ positioned at various locations including stations, platforms and on trains who can supply customised assistance, or guide passengers’ behaviour depending on the situation were defined. Node 5-5, ‘other passengers’ were contained as their behaviour and waiting patterns could influence passengers’ decisions about waiting positions and carriages to board. Lastly, node 5-6, ‘manageable luggage and mobility devices’ denoted the positive implication of supporting passengers to transport luggage or other mobility devices including wheelchairs easily. Since luggage had an impact on passengers’ control perception on walking speed and passenger flow (Huang et al., 2019).

## **3.6. Social organisation and cooperation analysis (SOCA) – Contextual activity template (CAT)**

The SOCA-CAT organised constraints of the system selected from the AH in a series of situations focusing on two types of actors: i) time-restricted traveller and ii) flexible traveller. Absence or presence of the possibility of the impact of the constraints were visualised (see Figure 2). Descriptions of each constraint are given as follows. Providing train and carriage occupancy information could be used throughout the journey before boarding for both types of users. The reason is that the information could help passengers choose which train or carriage to take when booking at origin, en-route to station or on the platform. Further, it could affect their decision to move to a less busy carriage after boarding the train. Occupancy information is typically provided at the station and platform, but the information of the booked train could be offered before passengers reach the station. Provision of general multi-modal public transport information may have a greater effect on time-flexible users because they could consider using alternative modes throughout their journey planning and implementing stages. On the other hand, the information would have a limited effect on time-restricted users because their purpose is to reach destination in time, thus they would adhere to the train initially chosen. To show delays and cancellation, and to display calling patterns could affect passengers’ decision at all the defined stages as basic service information. It can be considered in journey planning alongside crowding information by both types of passengers. Furthermore, train formation is typically displayed before departure at the station or platform, but it would be more effective if the information is available at origin or en-route to station, so it can be considered early in their decision making. The functions of those kinds of information would affect both types of passengers. Support of navigation and enabling easy access to platform would need to be provided for any journey types especially at the station and platform. Relevant information could be useful even before passengers get to station. By providing guidance on how to access the correct part of the platform easily by communicating which entrance, stairs or escalator/lift to use would enable them to have a more realistic plan in the journey planning stage. Financial transaction is typically enabled at the situations between origin and station as passengers need a valid ticket to pass through a ticket barrier. However, it could take place at the later stages as it is still possible to purchase or upgrade tickets on board. The effect would help both user types. Communicating offerings can be effective at stages in which travel planning and ticket purchase are usually conducted. The function would have an impact on both user types. Supporting passengers’ physical needs can be typically performed at the station and platform for both user types. However, request of special assistance could be made in advance and during the journey.

|  |
| --- |
|  |

**Figure 2. Social Organisation and Cooperation Analysis - Contextual Activity Template (SOCA-CAT)**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **: Empty cells**: functions are not possible in these situations. | | |
|  | **: Cells surrounded by dashed line**: functions could occur in these situations but typically do not. | | |
|  | **: Cells with balls and whiskers**: functions are able to and typically occur. | | |
| C:\Users\44774\AppData\Local\Microsoft\Windows\INetCache\Content.Word\Actor Shades.jpg | **: Time-restricted user** | C:\Users\44774\AppData\Local\Microsoft\Windows\INetCache\Content.Word\Actor Shades.jpg | **: Time-flexible user** |

# **4. Discussion**

This section proposes insights into why passenger behaviour change should be supported and how it could be achieved based on the analysis of the AH and the SOCA-CAT. For the development of the insights, nodes connected to the behaviour changes: 1) carriage selection and 2) train selection positioned at purpose-related functions (level 3) were reviewed thoroughly. To address why those behaviour changes are required, connected nodes at values and priority measures level (level 2) were used for the explanation. To address how to promote those behaviour changes, nodes at object-related processes level (level 4) linked to the behaviour changes were considered in the discussions. In addition, connected nodes at physical objects level (level 5) were utilised to develop insights into how to facilitate the connected objected-related processes. Further, it revisits the effects of occupancy information as a facilitator of behaviour change and offers room for improvement. Interpretations from the SOCA-CAT analysis were integrated into insights about behaviour change in terms of when and where some of those actions could be better assisted. The information from the SOCA-CAT is clearly marked to differentiate it from the input from the AH.

## **4.1. Insights into why changes in passengers’ behaviour are needed**

Defined behaviour changes (carriage selection and train selection for enhanced seat availability) are required as they could contribute to the values and priorities identified at level 2. The successful behaviour changes could be linked to benefits such as more available seats, increase in personal space and privacy, productivity when intending to work, safety and security, sense of control and value for money. Furthermore, timeliness could be improved that will benefit both passengers and the operator.

## **4.2. Insights into how to support passenger carriage selection**

Behaviour change in carriage selection could be facilitated by the majority of the object-related processes in the AH. They could be enabled by all the physical objects at level 5 (see Figure 3). The nodes which enable financial transactions and provide offerings and discounts were not connected to carriage selection because most passengers on the platform had already chosen which train to use and purchased the ticket. Thus, the supports they would need at this point are assistance with locating and accessing an emptier carriage. This could be facilitated by the object-related processes as follows: effective communication of information about carriage occupancy, facilities and services, assistance in navigation on the platform and in the station and support for locomotion as well as physical/psychological needs. Where only one of these are provided and the others are omitted, there is likely to be less effective behaviour change regarding carriage selection.

|  |  |
| --- | --- |
| **Level1**  Functional purpose |  |
| **Level 2**  Values & priority measures |
| **Level 3** Purpose-related functions |
| **Level 4** Object-related processes |
| **Level 5** Physical objects |

**Figure 3. Nodes connected with the function ‘carriage selection’**

|  |  |  |  |
| --- | --- | --- | --- |
| 2 | Potential behaviour change | 2 | Nodes linked to the behaviour change |
| 2 | Nodes not directly linked to the behaviour change | | |

***Note***: All the nodes identified in each level are demonstrated in Appendix A

#### **Informational support for passenger carriage selection**

Effective communication of information will play a major role in meeting passengers’ needs for information by reducing uncertainty associated with carriage selection. This will enable passengers to make better informed decisions to increase the probability of getting a seat by helping them have a more precise and practicable plan to access an emptier carriage. Related informational support needs to consider the provision of historical and real-time information about carriage occupancy where possible. In addition to this, basic information about the service should be taken into account (e.g. departure and arrival times, delays, cancellation, disruptions, route and calling patterns and number of carriages). The provision of carriage occupancy information in conjunction with estimated train arrival information is considered essential for passengers to decide whether it is practical to move along the platform to board an empty carriage or not. In the decision-making process, they need to gauge the degree of carriage occupancy of the arriving train, and how much time they have to move to an empty carriage before boarding. This could require more careful planning if there are multiple platform entrances. The SOCA-CAT highlighted that if carriage occupancy information is supplied early (e.g. at the journey planning or ticket purchasing stages), it could help increase the likelihood of securing a seat, for example by reservation. It also indicated the necessity to provide the general service information including train delays, cancellation and calling patterns throughout the stages. Moreover, passengers take a variety of additional information (e.g. carriage formation such as position of first class and carriage facilities) into account when making travel decisions, such as getting a seat, being able to work on the train, accessing tables, power, toilet and refreshment facilities. This would be beneficial for both time-restricted and time-flexible passengers, as indicated as the effect of ‘display train formation’ in the SOCA-CAT. Various physical elements are engaged in the passengers’ carriage selection process according to the analysis of the connected nodes at physical objects level. First, media conveying real-time dynamic information could include information displays located at the station and the platform, information desks, announcements from the station, platform, and train. Furthermore, general or rail specific transport mobile applications or websites could be useful. Second, media conveying static and historical information could include signage, adverts, posters, and leaflets. Third, ticket offices, help points, personnel and other passengers can be useful channels to ask for timely and tailored information. The authors advise providing carriage occupancy information through various channels as early as possible as confirmed in the SOCA-CAT. This may help passengers to choose a carriage for enhanced seat availability early enough to arrange an optimal route to the targeted carriage.

#### **Assistance for navigation**

Furnishing passengers with assistance in navigation on the platform as well as in the station would clearly help them to decide whether to move or not, or where and how to approach the target carriage. More specifically, supporting passengers to locate themselves on the platform and in the station in relation to the required carriage would be beneficial. Enabling easier access to the correct part of the platform to reach the targeted carriage (especially if there are multiple platform entries, or station entrances on different sides of the station) would also benefit passengers. By informing passengers of station layout, they could develop an appropriate cognitive plan on how to navigate within the station and on the platform in a more accurate and timely manner. The SOCA-CAT suggested that relevant supports are typically provided in the station or on the platform but could also be offered at earlier stages, such as at the origin or en-route to the station. This could be accomplished by offering information about how to access the right part of the platform more easily. A wide range of physical objects in the AH could be employed: websites, smartphone applications, signage, on-station and on-platform displays, ticket office and gates, trains (coach information, direction of travel), help points, platform facilities as landmarks. In addition, personnel and other passengers could provide wayfinding guidance.

#### **Support physical/psychological needs and locomotion**

Supporting passengers’ physical/psychological needs and locomotion could facilitate passengers’ decision to move to wait at the correct part of the platform. Relevant assistance is provided typically at the station or the platform, but in some cases, special arrangements may be needed at the booking stage or prior to departure as identified in the SOCA-CAT. This could enable passengers to get to the platform and board a carriage utilising suitable facilities or staff (Chen et al., 2019). Aid in transporting luggage would be helpful for passengers to access and walk on the platform especially for those with heavy baggage or mobility-impaired users and those with mobile or sensory dysfunction (Chen et al., 2019). In addition, providing protection from harsh weather elements seems beneficial because they create barriers to moving and waiting on the platform especially in uncovered areas. Visibility should be provided in areas with poor lighting where passengers could feel unsafe (Chowdhury and van Wee, 2020). Furthermore, helping make passengers feel safe while waiting at any parts of the platform by offering enough security may be needed. Offering the support mentioned above could be enabled by using related physical facilities on the platform and in the station. They include stairs, lifts, escalators, toilets, benches and cafes, adequate platform covering and lightings to help passengers reach and wait at the correct part of the platform more comfortably before boarding. Moreover, staff assistance can be effective directly or indirectly, for example, by transporting luggage, or providing guidance so passengers can reach platforms easily. This could be facilitated by using lifts and escalators for passengers with limited mobility. Furthermore, help points could be used as a tool to ask for assistance. Assistive information for passengers to plan their way to the correct part of station, platform and carriage should be provided. This could be accomplished with the use of rail related websites, smartphone Apps, personnel, or other passengers. Information displays, platform and train announcements could be advantageous to encumbered passengers allowing hands free information acquisition when having to handle luggage.

## **4.3. Insights into how to support passengers’ train selection**

The desired behaviour change for train selection could be promoted by several object-related processes identified in the AH (see Figure 4). To better encourage passengers to choose a less busy train, effective communication of information (including train occupancy and service information), promotion of monetary benefits, and assistance in physical and psychological needs at the station and platform would be beneficial. Where provision of information is conducted in isolation, without consideration of these other object-related processes, the success of a behaviour change intervention is likely to be limited.

|  |  |
| --- | --- |
| **Level1**  Functional purpose |  |
| **Level 2**  Values & priority measures |
| **Level 3** Purpose-related functions |
| **Level 4** Object-related processes |
| **Level 5** Physical objects |

**Figure 4. Nodes connected with the function ‘train selection’**

|  |  |  |  |
| --- | --- | --- | --- |
| 2 | Potential behaviour change | 2 | Nodes linked to the behaviour change |
| 2 | Nodes not directly linked to the behaviour change | | |

***Note***: All the nodes identified in each level are demonstrated in Appendix A

#### **Effective communication of information for passenger train selection**

Effective communication of information would perform a major role in supporting passengers’ train selection. It would benefit passengers to set a more realistic plan to choose an emptier train by considering estimated train occupancy along with additional information, including services and fares. Provision of basic service information is clearly needed, particularly scheduled, and modified up-to-the minute train departure times, disruptions including cancellations and delays (Stanton et al., 2013), as well as calling patterns alongside train occupancy information. Real-time train occupancy information is preferred to historical information for travel decision making (Kim, Lee and Oh, 2009), and may be more effective in behaviour change (Stanton et al., 2013). These types of information could help passengers not only to identify the less busy trains, but also to judge if it is practical and possible to modify their plan to use a less busy train by travelling at a different time. It is recommended to provide the train occupancy information as early as possible for passengers to make relevant arrangements in time as indicated in the SOCA-CAT. Any cost implications of getting an alternate train would also be needed to make an effective decision. Additionally, passengers would need to be informed as to whether the train meets their specific travel requirements, such as using carriage facilities. As presented in the SOCA-CAT, relevant information is typically offered at the station or platform, but such information is advised to be provided at the point of journey planning and ticket purchasing. A wide range of information resources can be deployed, such as general or rail specific websites and smartphone Apps, information systems at the station and platform (information displays, station and train announcements, signage, information desks, ticket office, and help points), personnel, and other passengers. Information channels that allow passengers to ask for tailored information would be particularly useful to meet their specific needs.

#### **Promotion of financial benefits**

Passengers could be encouraged to consider taking a less busy alternative train if they can get monetary benefits. Providing promotional offerings and discounts could facilitate them to select a cheaper train that leaves earlier or later. This can be typically effective at the ticket purchase stage (origin, en-route to station and station), however it could also be effective on the platform or train for upgrading tickets according to the SOCA-CAT. To support this, financial transaction should be enabled during journey planning, ticket purchase and amendment stages. This can be typically executed at origin, en-route to station and at station. In addition, it could possibly be performed on the platform and train as shown in the SOCA-CAT. This is in line with the necessity to improve payment flexibility to respond to various needs and disturbances (Read et al., 2015). Modifying the travel plan or ticket may not be appropriate for time-restricted travellers including commuters who must get to work on time, or passengers who hold time specific tickets. Therefore, relevant behaviour change is more likely to occur among time-flexible passengers who can choose an off-peak train (Preston, Pritchard and Waterson, 2017). Successful behaviour change was reported at 23% for Early Bird, “fare-free transit service” ticket holders who had decided to move their journey away from morning peak (Lovrić et al., 2016). Pertinent information can be offered on rail-related websites and ticket office. Mobile devices can be an efficient tool to plan, modify and make a transaction on the move, amongst others (Read et al., 2015).

#### **Support physical/psychological needs at the station and platform**

It is advised to accommodate passengers’ physical needs to enhance comfort whilst waiting for later trains. For example, full platform needs to be sheltered to protect passengers from bad weather elements. Since harsh weather conditions were negatively associated with public transport use (Miao, Welch and Sriraj, 2019). In addition, sufficient seating area should be arranged for passengers’ comfort. Adequate lighting is also necessary for passengers’ safety perception when waiting after dark. They should be provided all along the platform to encourage passengers to disperse the full platform length. Passengers’ physical needs can be assisted by suitable physical objects such as benches, toilets, waiting rooms, cafes, and full platform covering and lightings. Help points, personnel and other passengers can be sources of ad-hoc or customised advice.

## **4.4. Revisiting the effects of occupancy information**

The AH has depicted positive consequences of providing occupancy information to enhance the likelihood of securing more space and seats for passengers. Stress relief and improvement of passengers’ safety, security, productivity, and sense of control are expected as a result. To maximise these positive impacts, practices worth implementing alongside occupancy information have been highlighted. It will be advantageous to provide occupancy information through diverse channels. Along with this, it will benefit passengers to be able to access the information as early as possible as verified in the SOCA-CAT. Decision-making processes associated with behaviour changes are likely to be assisted by occupancy information alongside various functions of physical and non-physical aspects in the system as identified in the AH. For the occupancy information to be more effective to stimulate the desired behaviour change, these other constraints need to be taken into account. Without this consideration, supports for behaviour change through occupancy information are likely to be minimal, or even thwarted entirely.

# **5. Conclusions**

This study aimed to create applicable insights to promote passengers’ behaviour change by providing occupancy information to help moderate train overcrowding based on systematic understanding about constraints in the system. This was motivated by recognising the capabilities and limitations of providing train occupancy information as a tool to stimulate passengers’ behaviour change regarding train and carriage selection. To better support passengers’ informed decision-making that precedes changes in behaviour, a holistic analysis of the system was performed through CWA techniques. An AH comprised of goal-related constraints was developed with the ultimate purpose to enhance passengers’ satisfaction and comfort through greater access to seated travel. A SOCA-CAT was established based on the key constraints related to behaviour change focusing on time-restricted and time-flexible users.

Insights into passenger behaviour change regarding carriage and train selection were suggested through the analysis the AH and the SOCA-CAT. For both cases, enabling effective communication of information seems beneficial for passengers to identify, choose, and access the carriage or train they want to board. Offering not only real-time occupancy information, but also general service information about departure, arrival and disruptions is key. It would be beneficial to provide such information for both time-restricted and time-flexible passengers to make an informed decision at an earlier stage, preferably at the planning or ticket buying stages. It would also be advantageous if passengers can request and gain tailored information and achieve timely guidance from staff. For carriage selection, additional aids in meeting physical needs and locomotion in the station will be needed, particularly for passengers with limited physical capability with luggage. Furthermore, navigational support in the station and on the platform is essential and this could be offered at the planning stage. Moreover, reduction in passenger density on the platform is necessary for passengers to move with ease. For train selection, promoting offers and discounts could motivate passengers, especially time-flexible travellers, to modify their travel plan to take a less occupied train leaving earlier or later whilst also gaining a financial benefit. Financial transaction should be available for the amendment of tickets associated with rescheduling online if the decision is made on the move. Waiting passengers’ physical and psychological needs should also be accommodated. The AH has shown that diversifying the channels of occupancy information, assisting passengers’ physical needs and navigation at the station and the platform will promote more successful behaviour change than providing occupancy information alone.

Implications of this study are presented as follows. First, it extends the current knowledge on passengers’ behaviour change preceded by real-time occupancy. A key contribution of applying CWA in this context was the identification of the wider system constraints that impact behaviour change. While the provision of occupancy information is supported, the insights gained from CWA show that a more holistic suite of interventions is required to effectively support behaviour change. Through the process, improvements of our understanding on behavioural constraints in the rail service systems (which previous trials lacked) were made. Moreover, such constraints have not been extensively investigated in the existing studies on travel behaviour change explained by attitude-based theories. Those constraints could be used as potential factors that may affect traveller behaviour change for future hypotheses. This may help improve explanatory power of the attitude-based theories by testing better articulated models through inclusion of the identified constraints. Furthermore, values were suggested which passengers might pursue when using less busy services and getting a seat by investing effort to change their behaviour. This will facilitate understanding about why passengers would want to change their behaviour. Second, the application of CWA has generated practical guidance that could promote passengers’ behaviour change linked to the selection and use of less busy services. This was achieved by identifying goal-related constraints that may affect passengers' behaviour by considering their means-end relationships. This provides insights to service providers to create the physical and online rail service systems to better assist passengers’ behaviour change with an improved understanding about the constraints in the environment. Enhancement of passengers’ travel experience and mitigation of train overcrowding are expected as a result.

One of the limitations of this study is that the questionnaire sample included only a small portion of older adults. Thus, the findings derived from the data might not have represented their opinions sufficiently. The SME and focus group inputs were also unbalanced in terms of gender. Therefore, future studies should explore the impact of behavioural constraints on the activities of more balanced age and gender groups with differing physical abilities and perspectives. The SOCA-CAT could be reapplied for aid further investigation.

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**Appendix A**

|  |  |
| --- | --- |
| **Level** | **Identified node** |
| **Level 1**  Functional purpose | * Customer satisfaction with seated travel * On-board comfort with seated travel |
| **Level 2**  Values  &  priority  measures | * Stress-relief * Safety and security * Value for money * Timeliness * Productivity * Sense of control * Personal space * Seats available * Privacy |
| **Level 3**  Purpose  -related  functions | * Respond to risks/hazards * Weigh up opportunity cost * Access discounts/offers * Purchase e-tickets * Use Apps, websites * Mode selection (for seat availability) * Train selection (for seat availability) * Carriage selection (for seat availability) * Platform positioning (for seat availability) * Traverse the train (for seat availability) * Secure a seat * Maintain passenger flow * Assist less physically able users |
| **Level 4**  Object  -related  processes | * Display train formation (number of carriages) * Show waiting time * Identify carriage facilities * Identify empty carriages * Visualise estimated seat demand * Provide dynamic information * Display static information * Communicate information * Provide targeted/customised route/occupancy info * Provide historical trends for train/carriage crowding * Provide RT service info (routes, times) * Provide RT train/carriage crowding info (platform/carriage) * Provide train specific info * Provide general public transport information (multiple modes) * Show delays/cancellation * Display last minute platform changes * Display calling patterns (platform/carriage) * Portability of devices of information * Reduce passenger density on the platform * Support navigation (station/platform) * Locate own position on the platform * Provide landmark on the platform * Enable easier access to platform * Enable financial transaction * Communicate offerings * Promote discounts * Enable luggage transportation * Aid platform visibility * Provide shelter from weather on the platform * Reduce vigilance * Free hands for other tasks * Increase speed of locomotion on the platform * Support physical needs (station/platform/carriage) * Provide platform entertainment |
| **Level 5**  Physical  objects | * General transport App/websites (Google Maps/Transport for London) * Rail Apps/Rail websites (National Rail Enquiries, Trainline) * Mobile phones * On station display * On platform display * On train display * Information desk * Station and train announcements * Signage * Adverts * Printed materials (posters, leaflets) * Ticket office * Ticket gates * Trains (windows/carriages/coach number) * Tickets (seat information) * Personnel (drivers/on-board, platform staff) * Other passengers * Help points * Stairs/escalators/lifts * Benches on the platform * Toilets on the platform * Waiting rooms * Cafe * Platform design (size, shape, layout) * Better platform covering * Manageable luggage, mobility devices/wheelchairs * Adequate lightings |