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## **ENERGY, CARBON AND ENVIRONMENTAL IMPACTS OF PEDESTRIAN FLOW MANAGEMENT CONFIGURATIONS IN TRAIN STATIONS: WHICH LINK TO MODAL SHIFT?**

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### **1. INTRODUCTION**

For a long time, public transportation was rather considered for its technical aspects. In 2019 in France, the mobility orientation law has been voted and brought into law new thoughts about transportation: each travel is as dependant on the existing system as on passengers' personal experience and needs. In addition, this regulation underlines the environmental emergency to change our mobility habits. According to the French prime minister, modal shift towards public transports may permit a greenhouse gas decrease of 14% by 2030. Thus, the future of mobility leans on train station's ability to challenge the growing use of cars (Baron and Roseau, 2016). The latter is, literally and figuratively, the entrance gate towards a more carbon-free mobility. At the same time, its functioning is allowed by multiple devices (escalators, lifts, informational boards...), and these devices consume themselves carbon and energy. As the SNCF group has launched a ten-year program to reduce its operating buildings' carbon footprint (SNCF Réseau, 2017), one question that comes in mind is: should we reduce train stations' carbon footprint by limiting the number of these devices?

At first glance, the answer could be "yes": having less comfort won't stop the stations to fulfil their role. But we argue that this question must be integrated into a wider consideration. There are no useful train stations without passengers, and this is a reason to focus on their most important needs. Thus, we must find a way to bring together both users and environmental goals in the train station conception. Indeed, we can't decide on whether we should add or remove a device only by measuring its carbon footprint if this structure gives the user a better experience encouraging them to prefer public transport to cars on the long term. In this paper we will use a new indicator to assess a device's relevance ( $tCO_2eq/pass$ ) and then wonder if this tool is sufficient to make a decision by measuring their perceived importance level for passengers. We'll then provide first elements from our methodology and give a first

comparison between the carbon cost of a pedestrian overpass and its potential impact, showing the importance of evaluating both sides of the equation.

## 2. STATE OF THE ART

### 2.1 Very different carbon investments

In 2020, an environmental regulation (“Réglementation environnementale - RE2020”) was introduced into French law and made obligatory the use of the Life Cycle Assessment (LCA) method to measure environmental impacts of buildings. For now, only office areas within train stations need to comply with these obligations: the method is not mandatory for train stations and infrastructure projects. However, the method itself is interesting to assess the environmental impact of such projects and may be mandatory in the future. We then decide to use a similar method to assess stations conception. We draw inspiration from the “RE2020” reglementation methodology and assess the carbon footprint derived from materials consumption used in a train stations refurbishment projects. We presented this approach in a different paper to be published in 2023 (Suddaby *et al.*, 2023).

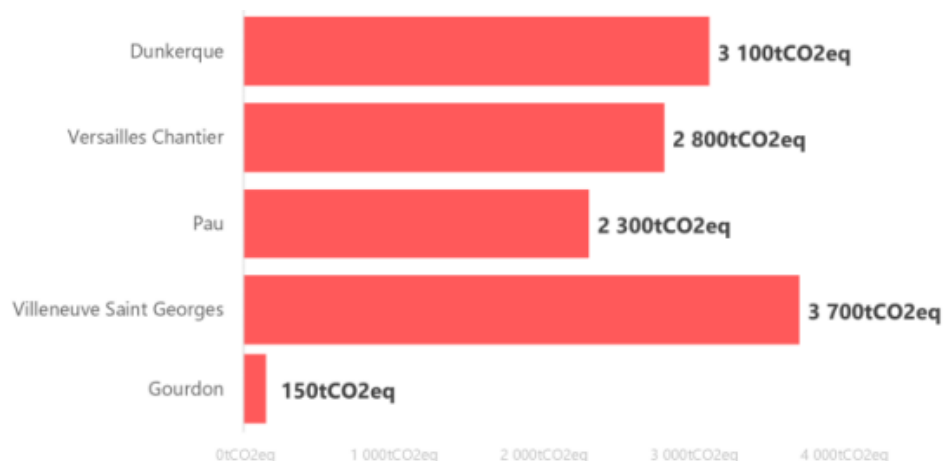


Figure 1 : Train stations' carbon footprint

The Figure 1 shows differences in terms of carbon footprint but this information needs to be contextualized: train stations are also characterized by their attendance level and geographic localisation. Nevertheless, we can wonder whether we should find a reasonable and common carbon footprint per passenger.

### 2.2 Carbon footprint of pedestrian flow equipments

With this analysis (over 50 years) we can identify the most carbon consuming device. Results show that flow systems such as escalators, lifts and stairs in a train station have the main environmental impact: they represent 15% of the whole station's

carbon footprint in France (Figure 2). With the aim of a greater sobriety, we first wonder if these devices are relevant based on the attendance level criteria. The escalator is greater in terms of capacity per minute (it can bear 90 passengers per minute). The idea is to observe which of these three devices has the best ratio carbon footprint/capacity efficiency. To move 90 passengers per minute, a train station should add 17 elevators which is both carbon and space consuming. Whereas, for stairs the resulting additional carbon footprint to reach 90 pass/min is very low and mostly, stays under the escalator’s global one.

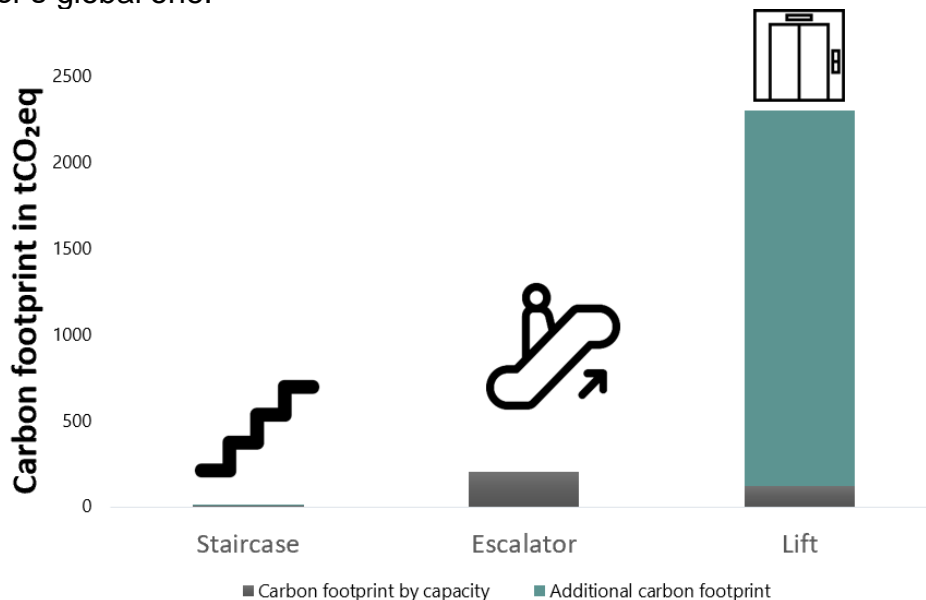


Figure 2: Carbon footprint (in tCO<sub>2</sub>eq) comparison for 90 passengers per minute

It is important to underline the fact that these three devices have different traffic objectives. Elevators are not made to absorb a high traffic but rather to offer a suitable accessible level. However, the selecting process can, in theory, be made between stairs and escalators. Thus, the tCO<sub>2</sub>/pass metric can assess the device’s level of relevance: we suppose the frequency level is a good indicator of usefulness. We choose the “Versailles Chantiers” train station case to illustrate how can this unit become a decision-making tool. In 2016, they planned to implement a new crossing infrastructure to create a juncture between the passenger building and platforms. The low frequency level observed in this structure was responsible for a relatively high ratio “carbon footprint/ frequency level” which led to the abandonment of this project. Given that, the tCO<sub>2</sub>eq/pass has been a rather great indicator to integrate in the decision-making process as it was pertinent before the carbon-based materials consumption.

To sum up, this indicator can be used to compare stations’ equipment between themselves to make the most sober choices. To come back to traffic systems, the difference between escalators and stairs lies on the comfort level: how important is this additional comfort in train stations for passengers? It is important to understand if

the reduction of the carbon footprint of train stations does not have a negative impact on their attractiveness to passengers, and by consequence decreases train travel, this would, at some point, have a global negative effect on the carbon footprint of the transport system.

### **2.3 Link between comfort, mode choice, and modal shift**

Station comfort in train station is a polysemous and subjective notion that researchers and operators are trying to standardize. According to the French operator “SNCF Gares et Connexions”, it is also a component of user satisfaction<sup>i</sup> which depends on “information, travel to the station, cleanliness and safety, time spent at the station (i.e. comfort) as well as services and shops” (Décret n° 2012-70, 2012). Again, the term “comfort” is not clearly defined as we can suppose there is an interdependence between cleanliness or safety and perceived comfort. In fact, comfort is not really a satisfaction trait but rather a witness of the user satisfaction: comfort is the perceived evaluation of all the attributes cited above. For this study, we decide to focus on train station as we consider they are an inevitable crossing point before taking the train. The literature about comfort in train stations is rare whereas train stations’ facilities are likely to have a greater importance if spending time in it takes a large portion of the total travel time (Hansson *et al.*, 2019).

Modal choice studies are various and have evolved over time. Since the 1970’s, modal choice is the result of cost, time and comfort (Brisbois, 2010). On one hand, many actual research confirm these affirmations and show that time travel is the most important attribute impacting modal choice (Brisbois, 2010) (Pearce *et al.*, 2020) (Hansson *et al.*, 2019). This attribute can be objectively measured (effective time travel) but also subjectively (perceived time travel): 50% of public transportation users perceive the time spent as longer than reality (Brisbois, 2010). The perceived time is directly influenced by the user satisfaction as “the value of comfort increases as travel time increases” (Hansson *et al.*, 2019). Adopting a time travel approach could be a potential indicator of perceived comfort in train stations. On the other, the cost attribute is also defined as one of the main factor choices. Nevertheless, it is shown that the solution is not to lower public transport prices but rather to increase the level of comfort allowing an offer aligned with the indicated price (Redman *et al.*, 2013). In fact, the comfort attribute could be a relevant indicator to explain or enhance train use attractiveness. Actual studies, still consider both physical and individual characteristics as main role player in the chosen mode but have added attributes. If physical traits in the mobility system (such as price, accessibility, time travel...) can easily be identified and valued, individual ones are more complex as they nowadays consider social and economic criteria as well as personal experiences, goals or preferences which are difficult to list.

Even though, improving comfort leads to a better user experience but not to an increase in attendance (Redman *et al.*, 2013), a better user experience can “determine a retention behaviour” (Mugion *et al.*, 2018). This explains our choice to measure the risk of loss rather than the modal shift. Indeed, we see comfort as a long-term investment allowing cars modal share reduction in the future. Furthermore, by doing so, we neutralize the possible habits effect on using cars (Javaid, Creutzig and Bamberg, 2020). Comfort is not the only word used to describe passengers’ experiences. Indeed, what is being studied is actually discomfort because it is a more objective notion (Loriquet, 2017). Discomfort is a co-existing attribute that needs to be considered to create a pleasant environment: adding comfort without reducing discomfort is a counterproductive strategy.

Effect of comfort on modal shift or, in this case, retention behaviour is supposed but rarely assessed. One of the purposes of this study will be to establish a potential causal link between added comfort (or reduced discomfort) in train stations and retention power.

### **3. METHODOLOGY AND FIRST RESULTS**

The state of art has permitted to establish a list of keywords related to comfort. These words can be divided into two categories: comfort linked to railway operation (frequency, speed, security, availability) and comfort linked to the well-being in the travel (safety, accessibility, cleanliness, information, fluidity). Our work focuses on users’ perceived comfort unrelated to the mobility functioning system. The first step of our research would be to make a general analysis of comfort impact in passengers’ experience. The SNCF group gathers several information made available in public databases. Since 2019, it possesses a customer satisfaction barometer at the station which goal is to question clients about the existing level of service. Other databases, contain data which make the inventory of comfort apparatus in stations. Given that, the objective is first to realize a statistical study on different train stations to know if there is a correlation between the given note and the availability of comfort equipment and then to classify this equipment in order of importance.

The station can be observed on two scales, sometimes functioning in contradictory ways. On the macroscopic scale we observe movements guided by the layout of the infrastructure while on the microscopic level, random and individual behaviours are practiced. The station is a lively space which can be characterized by movements it accommodates. The latter are the sum of several explanatory factors: the reason for travel, its speed, its rhythm, its experience, its route, its origin/destination (Cresswell and Lemarchand, 2015). What happens when the macroscopic level doesn’t meet the microscopic one?



We chose to work on the French train station “Saint-Cyr” (in Saint-Cyr-l’École, near Versailles) to observe effects of flow discomfort in passengers’ mobility behaviour. This station has been served since mid-2022 by Tramway T13 Express generating additional passenger flows and creating congestion in the underground passage. The questions are: what is the losing risk level created by this source of discomfort in the station? Is it positively impacting to reduce this discomfort?

Reducing this inconvenience comes down to invest in carbon by constructing a new crossing way. Our carbon study shows that a footbridge emits 1,500 kgCO<sub>2</sub>eq/m<sup>2</sup>, so for an average structure of 495 m<sup>2</sup>, the total carbon footprint would represent 742,500 kgCO<sub>2</sub>eq. By taking a basic itinerary from Saint-Cyr to Paris Montparnasse, a thermal car would cross 26 km and emit 10 kgCO<sub>2</sub>eq for the round-trip (French Government, 2023) and 0,104 kgCO<sub>2</sub>eq by train. By doing a small calculation, the overpass impact divided by the corrected travel impact (car travel emissions minus train travel’s ones) divided by the LCA duration of 50 years, we can affirm to write off the footbridge carbon investment, we should be able to attract at least 5 car travellers per day for 50 years. For this research, we wonder if this new bridge could have a long-term positive effect on actual users, so it deters them from choosing car in the future and permits to enhance the whole mobility system by reducing its environmental impacts.

#### 4. CONCLUSION

Train station are the gateways to a sober mobility. However, the role of their level of comfort to the modal shift are insufficiently known. This makes difficult to know the carbon impact of station improvement projects: on one hand, we’re able to determine the carbon consumption of the improvements and to compare different projects; on the other hand, it is complicated to know the positive or negative impact on train use, and therefore the carbon consumption linked to the use of other modes, particularly the car. In this paper, we propose a first calculation, and we show, that considering a lifespan of 50 years, the carbon consumption of a new pedestrian overpass in one particular station is equivalent to the car-related emissions of 5 people using their car for a typical journey from the station. In other terms, if the implantation of the overpass prevents at least 5 persons doing the journey daily to switch to car, it is a good carbon investment within 50 years. In future research, we will try to quantify the potential modal shift to determine if the overpass (or similar structures such as escalators) are actually good carbon investments. We plan to use a declarative approach by the travellers to assess the potential for modal shift. We will also apply this methodology more systematically for stations, to gather more complete data on this matter.

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## Notes

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<sup>i</sup> The feeling of satisfaction results from a confrontation between the level of service observed and that expected.