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The outbreak of COVID-19 demonstrated the fragility of the transportation system and its Multimodal Transport Hubs (MTHs). Global travel reduced dramatically, leading to an existential crisis in MTHs. To cope with the pandemic, MTHs implemented multiple resilient measurements including social distancing, rapid testing regimes, and infrared cameras. Although these measurements are valuable tools, this research advocates to transcend resilient measures and move towards antifragility by applying a systems thinking approach. As Nassim Taleb (2013) defines: “Antifragility is beyond resilience or robustness. The resilient resists shocks and stays the same; the antifragile gets better.” Our goal is to contribute to a long-term future of the transportation system by transforming MTHs into a tool to effectuate antifragility during the management of health disruptions.

Keywords: Design for Antifragility, Pandemics & Systems Thinking

Introduction

In December 2019 the world was exposed to a novel coronavirus: SARS-CoV-2 or COVID-19, originating from Wuhan, China. Initially, COVID-19 was perceived as a regional epidemic, comparable to SARS-CoV-1 or MERS, but rapidly spread worldwide. Mid-February 2020, high transmission rates were found in countries worldwide including the Islamic Republic of Iran, Italy and Spain leading to the World Health Organization (2020) officially labelling it a pandemic on the 11th of March 2020. In the following weeks, the global transportation system collapsed, with air traffic hitting an all-time low in Europe on the 12th of April of 2.099 flights; a reduction of 92,8% compared to 2019 (Eurocontrol, 2021).

Although air traffic is slowly recovering, COVID-19 showcased the fragile nature of the transportation system and their Multimodal Transport Hubs (MTHs) in managing health disruptions. MTHs, such as Amsterdam Airport Schiphol, function as the backbone of modern-day transportation by facilitating the consolidation of different global (e.g. aviation), regional (e.g. train) and local (e.g. bus) modalities. Although efficient and economic from an operational point of view, the coalescence of multiple travel flows can rapidly facilitate the spread of diseases on an international scale.

MTHs have been implementing a wide array of measures to mitigate the pandemic ranging from social distancing and rapid testing regimes to infrared cameras. Although these measures offer a degree of pandemic resilience, they often are reductionist measures instead of system-level redesigns. The COVID-19 crisis forms an opportunity for a systemic reinvention of MTHs, making it a tool in managing future health disruptions rather than a spread accelerator.

This paper is part of a PhD-research collaboration between Delft University of Technology and the Royal Schiphol Group. The aim of this paper is to conceptualize the relevance of pandemic antifragility for MTHs and propose directions for future research.

The paper is structured in three sections. Section one elaborates on the pandemic fragilities of MTHs. Section two explains the spectrum of fragility. Section three explores antifragility in MTHs. Finally, the paper ends with a conclusion and proposal for future research.

Pandemic Fragilities of MTHs

Travel is a key accelerator in the spread of diseases. This can be seen throughout history; from the migration of the black plague by Medieval traders over the Silk Road, to troops movement during WW1 for the Spanish Flue and now, international air travel for COVID-19. Rapid technological advancements in global, regional and local modalities in combination with a highly networked transportation system and consolidatory MTHs facilitate quick and accessible travel. This offers great socio-economic benefits, but also significantly increases our society's pandemic fragility.

Currently, this research assumes that the pandemic fragility of MTHs consists of two dimensions: operational and systemic. The consolidation of global, regional and local modalities into MTHs allows for a non-linear spread of diseases, due to the convergence and divergence of global, regional and local travellers. Since managing the convergence and divergence processes forms the operational core of an MTH, we refer to all related issues as 'operational' fragilities. This phenomenon can be observed during the COVID-19 pandemic, where global and regional modalities significantly contributed to its spread (Sokadjo & Atchadé, 2020; Zhang et al., 2020; Coelho et al., 2020). Whether the spread of COVID-19 is mainly due to the transportation of pre-travel infected passengers, to in-travel transmissions or to in-terminal transmissions remains unclear up to now.

The 'systemic' fragilities refer to MTHs as part of a complex and layered transportation system, consisting of a wide range of actors. These actors can be traditional transportation actors, such as MTH owners, airlines, ground handlers, air traffic controllers, security services, transportation ministries and international organizations, but also relatively new actors, such as public health ministries and organizations. Creating and maintaining strong interfaces between all relevant actors during a health disruption, while avoiding misalignment and silo-mentality is a major hurdle due to the complex and niche environment. Failure to do so leads to slow and reactive governance instead of a quick and proactive one. This is undesirable, as time is of the essence when dealing with disruptions.

The Spectrum of Fragility

Since fragility is a central concept of this research, one must have a common understanding of it. Fragility, according to Nassim Taleb (Taleb, 2013), must be seen as a spectrum ranging from fragility to resilience and antifragility. Although nuances can be made between robustness and resilience (Ramezani & Camarinha-Matos, 2020), this research chooses a point of view wherein both concepts are interchangeable.

To explain the spectrum of fragility, Taleb (2013) uses three ancient Greek mythologies (figure 1): The Sword of Damocles, Phoenix and Hydra. The Sword of Damocles portrays a fragile situation wherein Damocles is invited to a royal banquet by Dionysus II while a sword hangs, with one horsehair, above his head. Any disturbance can make the horsehair snap, ending Damocles' life. To generalise this allegory, a fragile situation deteriorates when exposed to disruption. The Phoenix tells the story of a mythical creature that can be reborn, or arise from its ashes, and return to its former state. This illustrates resilience or the ability to resist disruptions and staying the same. Finally, Hydra tells the story of a multi-headed creature that can regrow and double its heads whenever one is cut-off. This is the pinnacle of antifragility, using disruptions to grow, adapt and thrive.

Figure 1. The spectrum of fragility (Taleb, 2013): Fragility & the Sword of Damocles (Westall, 1812); Resilience & the Phoenix (Bertuch, 1806); Antifragility & Hydra (Cort, 1565)

Transcending instead of returning to its former state, is a key feature of antifragility. The antifragile self-improves and transforms by having an active learning capability which is key in coping with disruptions (Taleb, 2013). Note that the distinction between resilience, fragility and antifragility is not binary but a spectrum. Achieving 100% antifragility is impossible.

Towards Antifragility in MTHs

As illustrated in the previous section, the MTHs appear operationally and systemically fragile to health disruptions with COVID-19 being its most recent manifestation. Nevertheless, MTHs are trying to overcome current pandemic fragilities by deploying a wide range of, mostly resilient, measurements, such as social distancing, rapid testing regimes and infrared cameras. These measurements often use a reductionist approach by intervening in problematic parts instead of the transportation system as a whole. Avoidance of addressing the operational and systemic paradigms can make reductionist solutions unsustainable in the long-term.

For example, social distancing is impossible to maintain when having a high throughput of passengers. Rapid testing regimes are only viable when tests are developed for a certain pandemic making them reactive and case-specific. Although currently labelled as inefficient (FDA, 2021), infrared cameras were initially seen as a resilient COVID-19 diagnostics tool. Like rapid testing regimes, infrared cameras are only viable in a reactive way. Closing MTHs during a health disruption might be the logical solution in overcoming this pandemic fragility altogether, but this is difficult to implement and maintain due to adverse social, economic and political effects. The International Health Regulations set by the World Health Organization (2016) reinforce this by stating that "*unnecessary interference with international traffic and trade*"' must be avoided when dealing with the international spread of diseases. Additionally, the closing of MTHs is again a reactive measure, thus not preventing an initial spread of diseases. Note that we are not discrediting resilient measurements but indicating that by deploying them there is a tendency to lose sight of the underlying operational and systemic issues.

Applying an antifragile approach can offer an opportunity in addressing these underlying issues. Throughout the years, antifragile methodology has gained traction and has been, explicitly or implicitly, used in several industries ranging from ICT including Netflix (Tseitlin, 2013) and BitCoin (Ramezani & Camarinha-Matos, 2020); aerospace including NASA (Jones, 2014); and risk analysis (Derbyshire & Wright, 2014). The concept even found its way, implicitly, into airport security (Ghelfi-Waechter et al., 2018). Although explicit precedents of applied antifragility remain scarce, several design principles have surfaced in the ICT industry. Tseitlin (2013) suggests the usage of active failure induction, or a form of red teaming, and combining development and operational teams. Hole (2016) emphasizes modularity, weak links, redundancy and diversity while applying a fail-fast mantra.

This research proposes designing and implementing antifragile methodology in combination with a holistic systems thinking approach applied to MTHs. This approach aims to keep a holistic vision that is broader than the transportation system and also includes for example health, government and security actors. The ambition is to develop design knowledge for transforming the transportation system in dealing with pandemic disruptions. Additionally, a strong emphasis is put on proportional measures when dealing with health disruption ranging between unrestricted travel and closure of MTHs. Other disruptions are currently out of scope, but it is anticipated that pandemic antifragility can be extrapolated.

Conclusion and next steps

MTHs are susceptible to pandemic disruptions due to their consolidatory nature. To counter their operational and systemic fragilities, this research proposes to utilise antifragile methodology and a systems thinking approach. Following the ideas of Taleb (2013) and illustrated by Ramezani & Camarinha-Matos (2020), we propose that efforts must be put into learning, improving and transforming the transportation system so that MTHs can become a tool in managing health disruptions.

This PhD research will explore how to design for pandemic antifragility in MTHs with a strong emphasis on qualitative research. A central and continuously applied methodology is action research. As defined by Greenwood & Levin (2007), action research is a research strategy and reform practice that is used in the field, consists of multiple research techniques and is aimed at creating change and generating data for scientific knowledge. The methodology is highly collaborative and focuses on mutual learning between stakeholders. By applying action research, the PhD researcher is partially embedded in the organization of a large MTH, Amsterdam Airport Schiphol of the Royal Schiphol Group, offering first-hand insights into all its challenges.

As a first study, an in-depth analysis will be made regarding the pandemic fragilities, resiliencies and antifragilities in MTHs during the COVID-19 crisis. This is done by conducting semi-structured expert interviews. During the interviews, experts are asked to talk about their experiences and lessons learned throughout the COVID-19 pandemic. The study focusses on aviation as a global modality, since this modality contributed significantly to the pandemic spread and was heavily impacted. The interviews are conducted with actors inside and outside the transportation industry. It includes experts from MTHs, airlines, ground handlers, travel clinics, public health organizations, health ministries, transportation ministries and security services. The resulting interviews will be top-down thematically analysed based upon fragility, resilience and antifragility (Braun & Clarke, 2006). To determine fragility, resilience or antifragility, criteria by for example Taleb (2013), Hole (2016) and Tseitlin (2013) are used. Additionally, classification occurs based upon experiences being operational and/or systemic, time of emergence, degree of proactiveness, etc. New classification(s) may arise throughout the thematic analysis.

Lessons learned from both interviews and action research will form the starting point for designing antifragile interventions and/or frameworks in MTHs while applying a systems thinking approach. The ideal result would be a range of operational and systemic measurements which offer a proportionate reaction in dealing with health disruptions in accordance with the IHR (WHO, 2016). It is important to highlight that those measurements can be a combination of fragile, resilient and antifragile parts rather than the antifragile being one entity.

To guarantee a degree of antifragility, evaluation of the intervention(s) and/or framework(s) must occur. This is an integral part of the design process. It is anticipated that this will dynamically take place throughout the PhD in relation to the design process. Practically verifying antifragility is difficult and is predominantly achieved by exposing interventions or frameworks to stressors. The introduction of stressors will expose fragilities, giving the opportunity to overcome them and acquire antifragility. This concept of active failure induction, or a form of red teaming, is an avenue of interest in this research. Nevertheless, practical testing is not always possible in the MTH context due to high complexity, security reasons and continuous operations. Serious gaming might offer a solution by providing a qualitative but simulated testbed.

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