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Ready for digital transformation? The effect of organisational readiness, innovation, airport size and ownership on digital change at airports

Nigel Halpern [a,*], Deodat Mwesiumo [b], Pere Suau-Sanchez [c,d], Thomas Budd [d], Svein Bråthen [b]

[a] Department of Marketing, Kristiania University College, Post Box 1190 Sentrum, 0107, Oslo, Norway
[b] Faculty of Logistics, Molde University College – Specialized University in Logistics, Post Box 2110, 6402, Molde, Norway
[c] Faculty of Business and Economics, Universitat Oberta de Calunya, Av.Tibidabo, 39-43, 08035, Barcelona, Spain
[d] Centre for Air Transport Management, Cranfield University, MK43 0TR, Bedfordshire, United Kingdom

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ABSTRACT

This study investigates the effect of organisational readiness, innovation and airport size and ownership on digital change at airports. Data is collected from a survey of managers at 94 airports worldwide and analysed using partial least squares structural equation modelling. Organisational readiness is found to have a direct effect on digital change. Organisational readiness also has a direct effect on innovation, which subsequently affects digital change. Airport size has a direct effect on digital change while the effect of ownership is not significant. The findings show that successful development of organisational readiness can be used to speed up the rate of innovation needed for digital change at airports.

1. Introduction

Airports have embraced digital change, whether it is encoding analogue information into a digital format or using technologies to alter and add value to existing processes and functions. For some, change is now being driven by current or emerging technologies such as augmented reality (Eschen, 2018), Big Data Analytics (Mullan, 2019), blockchain (Di Vaio and Varriale, 2020), cloud computing (Amadeus, 2014), cognitive computing (Herrema et al., 2019; Sadjadi and Jarrah, 2011), cybersecurity (ACI, 2020), systems integration (Stocking et al., 2009), the Internet of Things (Mariani et al., 2019; Zmud et al., 2018) and virtual modelling and simulation (Ørsted, 2019). These technologies allow airports to develop systems that monitor, visualise and respond to digital processes and functions in real-time, and as part of a wider ecosystem that connects all stakeholders (Halpern et al., 2021). They therefore enable airports to implement ecosystem-level changes that are needed for digital transformation (ACI, 2017; Pell and Blondel, 2018).

However, digital change does not occur by accident. Instead, it requires strong investment across the organisation because the disruptive potential of change, especially for more mature stages of digital transformation, extends beyond technologies. It describes a paradigmatic shift in the way that technologies are adopted and used, and at an organisational level. The extent to which airports address organisational challenges associated with transforming their business is therefore expected go some way to determining digital change (Halpern et al., 2021). Despite this, organisational challenges associated with digital change have been overlooked in transportation literature where instead, the focus tends to be on technologies, for instance in terms of the use of them at airports or use cases for the future (Adey, 2004; Bouma et al., 2016; Chiti et al., 2018; del Rio, 2016; Eschen et al., 2018; Haas, 2004; Halpern and Regmi, 2013; Lee et al., 2014; Martin-Domingo and Martín, 2016; Straker and Wrigley, 2018; Wattanacharoensil and Schuckert, 2015); issues associated with passenger acceptance of them (Gures et al., 2018; Morosan, 2016; Negri et al., 2019; Wittmer, 2011); or their impact on passenger behaviour (Castillo-Manzano and López-Valpuesta, 2013), airport service quality (Brida et al., 2016; Chen et al., 2015; Pitt et al., 2002) or airport capacity (Kalakou et al., 2015). Knowledge of the organisational challenges remains largely anecdotal – described in the reports of industry associations or consulting firms advising airports how to prepare for digital transformation (ACI, 2017; Boutin et al., 2016; Pell and Blondel, 2018). There is therefore a lack of empirical evidence on what the challenges are and how they affect change.

Addressing the gap in literature, this study investigates organisational challenges associated with digital change at airports. The main focus is on the effect of organisational readiness. However, the effects of innovation and airport size and ownership are also examined. The

* Corresponding author.
E-mail address: nigel.halpern@kristiania.no (N. Halpern).

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findings are based on a survey of managers at 94 airports worldwide with data analysed using partial least squares structural equation modelling (PLS-SEM). Section 2 of this paper provides study context with a closer look at digital change at airports and the organisational challenges associated with it. Hypotheses to be tested in the analysis are also provided in Section 2. Section 3 describes the methodology in terms of the constructs and indicators used, sample characteristics, and the analytical approach. Section 4 presents findings of the analysis. Section 5 provides a discussion and conclusion that highlights main contributions, study limitations and recommendations for future research.

2. Study context and hypotheses

2.1. Digital change at airports

Digital change plays a key role at airports where current and emerging technologies are used for a range of solutions regarding process automation, customer engagement, intelligent building management, predictive solutions, collaborative decision making and flow monitoring and management (Blondel et al., 2015; Halpern et al., 2021). There is no start or end point to digital change. Instead it involves a continuous process of improvements. However, for most industries, it is possible to define several key stages that ultimately lead to digital transformation. Using a digital maturity model, Halpern et al. (2021) identify four stages an airport can go through: (1) Airport 1.0 Analogue, where the majority of processes are undertaken manually by staff and delays are experienced in the time taken to use any data that is captured; (2) Airport 2.0 Digitisation, where there is some use of digital technologies within the airport, for instance at check-in and security, and for passenger information and wayfinding in the terminal. Electronic data is captured and used retrospectively to inform decision making. Several open data initiatives are used to share data with key stakeholders such as airlines; (3) Airport 3.0 Digitalisation, where digital technologies are used extensively for the majority of airport processes, and to add value to airport functions over and above basic operational requirements. This might include eCommerce; self-service check-in and bag drop; scanners for mobile-based boarding passes; full body and computed tomography scanners at security; digital self-service information and location-based services; and the use of messaging applications. Electronic data is captured and used to inform decision making and shared extensively with key stakeholders. Some systems are interconnected such as those of airports, ground handlers and airlines to facilitate baggage handling; (4) Airport 4.0 Digital transformation, where value is created from data that is captured and shared with key stakeholders and used in real-time via smart data capabilities. This might include live queue times at security to be shown on airport express train services or the number of passengers entering the terminal to be shared with security or border control agencies to support resource allocation. Airport systems and processes are therefore integrated within the wider airport digital ecosystem that connects key stakeholders.

Airport 4.0 is synonymous with the 'smart' or 'connected' airport concept (Boutin et al., 2016; Fattah et al., 2009; Mariani et al., 2019; Nau and Benoit, 2017; Newbold, 2020; Zmud et al., 2018) and is the airport digital architecture for the future. Airports seeking to reach this level of maturity need to have digitalised key processes and functions. Not just for passenger and airside operations but for all aspects of the business including resource management, infrastructure management and administration. Such initiatives are covered extensively in transportation literature. For instance, Brida et al. (2016) show how airport information systems affect passenger perceptions of service quality at airport functional areas, while Eschen et al. (2018) examine use cases for augmented and virtual reality in airport inspection and maintenance processes. Several studies investigate the impact of self-service technologies at airports (Bogicevic et al., 2017; Castillo-Manzano and López-Valpuesta, 2013; Gures et al., 2018; Lee et al., 2014; Wittmer, 2011), while the use of airport digital channels such as websites, social media and mobile applications is extensively covered (Florido-Benítez, 2016; Florido-Benítez et al., 2016; Halpern, 2012; Halpern and Regmi, 2013; Inversini, 2017; Martin-Domingo and Martín, 2016; Straker and Wrigley, 2018; Wattanacharoensil and Schuckert, 2015).

Airport 4.0 relies on digitally connected networks of assets and physical entities, that can both receive and communicate data digitally to aid decision making. This is facilitated by instrumentation such as sensors or other smart components that gather data and communicate it across a network. The main types are proximity, pressure, optical and motion sensors (Halpern et al., 2021; Zmud et al., 2018). Airport initiatives involving sensors are covered extensively in transportation literature, for instance, regarding biometrics (del Rio et al., 2016; Haas, 2004; Kalakou et al., 2015; Morosan, 2016; Negri et al., 2019), people tracking (Adey, 2004; Bouma et al., 2016) and queue prediction (Chiti et al., 2018).

Data is vital for digital change at airports (Howell, 2016; Mullan, 2019; Papagiannopoulos and Lopez, 2018). At a basic level, airports collect data from a range of key processes and functions, analyse it and use it to inform decisions. There may also be some sharing of data with key stakeholders. However, those with the most advanced levels of maturity are expected to have connected and integrated systems and processes that collect data with those of key stakeholders so that data can be used in real-time across the wider airport digital ecosystem. The use of data, along with instruments and digital technologies for key processes and functions are recognised for their role in revolutionising and digitally transforming businesses (Iansiti and Lakhani, 2014), and are operationalised as constructs for the measurement of digital change in this study (Table 1).

2.2. Organisational challenges and hypotheses

As mentioned in Section 1, digital change, especially for more mature stages of digital transformation, is about more than technology. This is widely supported in the literature on digital transformation. For instance, Kane et al. (2016) state that it is not just about implementing

Table 1
Indicators for digital change (DIG).

Label	Description
TEC1	Passenger processes (e.g. check-in, bag drop, security, eCommerce, wayfinding, boarding)
TEC2	Airside operations (e.g. tower and ATC, gate and apron, airport control, airfield operations)
TEC3	Infrastructure management (e.g. building, energy, waste)
TEC4	Resource management (e.g. assets, workforce)
TEC5	General administration (e.g. accounting, payroll, procurement, Business Intelligence)
INS1	Proximity (e.g. parking space sensors, RFID smart baggage tracking, GPS tags for asset or workforce tracking, geofencing or passenger tracking via beacons, Bluetooth or wifi)
INS2	Pressure (e.g. sensors for smart energy monitoring, building maintenance, waste management)
INS3	Optical (e.g. cameras or other sensors for biometrics, security screening, flow or throughput management, or monitoring equipment such as aircraft, vehicles, kiosks and bag drop stations)
INS4	Motion (e.g. access control sensors for intrusion detection, video surveillance, automatic doors or barriers)
DAT1	Data is collected from a wide range of sources
DAT2	Data is analysed and used quickly to inform real-time decision-making
DAT3	Data is shared in real time with key industry partners such as ground transport, airlines, handlers, security, passport control
DAT4	Airport systems and processes that collect data are connected and integrated with those of key industry partners

Survey questions.
TEC: To what extent are digital technologies used at your airport in the following areas?
INS: To what extent are the following sensors or other smart components used at your airport?
DAT: To what extent do you agree about the following statements?

more and better technologies but about digital congruence that aligns culture, people, structure, and tasks of a company. Tabrizi et al. (2019) state that rather than being about technology, it is about developing an organisational readiness to succeed.

Organisational readiness can be defined as a state of preparedness that an organisation attains prior to commencing an activity (Helfrich et al., 2011). Such a state is often linked to positive outcomes like the successful implementation of new policies, programs and practices (Shea et al., 2014). It is expected to be significant for digital change because it determines the overall predisposition of an organisation to adopt technologies (Ferreira et al., 2014). Furthermore, it is unlikely that digital transformation can be realised if the organisation itself is not ready for it. In addition, technologies are highly disruptive and subject to constant change. Developing an organisation that is ready to anticipate and respond quickly is therefore crucial, not only for digital change but also for survival (Crittenden et al., 2019; Lucas and Goh, 2009).

Several studies have described what is needed to achieve organisational readiness in the context of digital change at airports. Mullan (2019) describes how organisational culture and capabilities are needed to build a data-driven airport while Newbold (2020) describes the need for collaboration to deliver on the promise of the smart airport. Pell and Blondell (2018) describe four key needs: strategic clarity and visible leadership support that is required to drive change; effective partnering and collaboration to learn about technologies, identify use cases, and share risks associated with their implementation; internal capabilities in terms of digital skills and resources; and a digital mindset and culture that is able to identify, prioritise and implement effective solutions. Similar needs are identified by ACI (2017) and Boutin et al. (2016). In their review of this literature, Halpern et al. (2021) identify four components of airport organisational readiness (clarity, collaboration, capabilities and culture) and 16 indicators that are used in this study (Table 2). Airports with higher levels of organisational readiness are expected to be more advanced regarding digital change. Hence the hypothesis:

H1. Organisational readiness has a significant direct effect on digital change.

This study argues that the rate at which airports adopt innovation is dependent on organisational readiness. This is supported by Lokuge et al. (2019) who claim that most new ideas fail to translate into new products or services due to a lack of organisational readiness. This is because to be good at sensing and adopting innovations, airports need to create a culture, develop organisational capabilities and encourage collaboration for innovation. They also need clarity to make sure that innovation closely aligns with the strategic objectives of the airport. Hence the hypothesis:

H2. Organisational readiness has a significant direct effect on innovation.

Innovation is subsequently expected to encourage digital change. The growing involvement of airports in innovation labs, hubs, accelerators or incubators is testament to this. The main objective tends to be to create and experiment with new technologies for different solutions therefore increasing the rate with which they can adopt new ideas and technologies. This links to Diffusion of Innovations theory, which is defined as the adoption and subsequent spread of technology within a social context (Vargo et al., 2020). The theory was introduced by Rogers (2003) who identifies five categories of adopter: laggards, late majority, early majority, early adopters, innovators. Laggards are expected to be characteristic of Airport 1.0 and among the last few airports to use new digital technologies. The majority (late and early) are Airport 2.0 and tend to use new digital technologies when they are used by other airports. Early adopters are expected to be developing Airport 3.0 characteristics, have a tendency to embrace new digital technologies, and be among the first few airports to use them. Innovators are the Airport 4.0s of the future and are expected to actively seek out new digital technologies and experiment with them, even when they have not been trialled much in an airport setting before. The categories of adopter by Rogers (2003) are used to measure innovation in this study (Table 3), and it is argued that innovation encourages digital change. Hence the hypothesis:

H3. Innovation has a significant direct effect on digital change.

Previous research has suggested that digital transformation is embraced by companies of all sizes including large global corporations (e.g. Warner and Wäger, 2019) and small and medium-sized enterprises (e.g. Ferraris et al., 2018). However, there are several challenges associated with investing in technologies at airports (Halpern et al., 2021). Cost is an obvious one but there are also challenges associated with: implementing and maintaining them; uncertainty regarding their lifespan, potential supplier lock-in effects, and achieving buy-in from stakeholders and market acceptance; and vulnerability regarding cybercrime, privacy and other social and ethical issues. This means that investment in the latest technologies may be more difficult for smaller airports. There may also be differences according to airport ownership. The requirement for investment is a key driver for airport privatisation (Graham, 2011), so airports owned by private interests are expected to be more advanced with digital change compared to those that are publicly owned. However, ownership is not straightforward because the range of airport privatisation models has now become so diverse (Graham, 2018). Also, there are many airport operators that are publicly owned but operated as corporations run at arm's length from their government owner. Many of these corporations operate large airports and/or airport systems that are able to benefit from economies of scale when implementing new technologies. Smaller airports in such groups may benefit from trickle-down effects from the larger ones and from

Table 2
Indicators for organisational readiness (ORG).

Label	Description
CLA1	Has a clearly defined digital strategy
CLA2	Has a clear leadership for digital initiatives
CLA3	Has senior managers that support and engage in digital initiatives
CLA4	Provides clear business cases for digital initiatives
COL1	Collaborates effectively with stakeholders on digital initiatives
COL2	Is good at channelling ideas or requests from stakeholders about digital initiatives
COL3	Learns from collaborating with stakeholders on digital initiatives
COL4	Is good at building support from stakeholders for digital initiatives
CAP1	Understands key digital technologies and how they can impact on airports
CAP2	Identifies and anticipates required skills and resources for digital initiatives
CAP3	Acquires and trains digital talents while valuing and retaining existing competencies
CAP4	Builds support for digital initiatives through solutions that work
CUL1	Has a positive attitude towards digital initiatives
CUL2	Has a dynamic approach to making decisions about digital initiatives
CUL3	Takes an organisation-wide rather than department-driven approach to digital initiatives
CUL4	Has a culture that recognises and values new digital ideas and initiatives

Survey question: To what extent do you agree or disagree with the following statements about your organisation? Our organisation.

Table 3
Innovation (INN).

Adopter	Description
Laggards	We are normally amongst the last few airports to use new digital technologies
Late majority	We tend to use new digital technologies when they are used by most airports
Early majority	We tend to use new digital technologies when they are used by some airports
Early adopters	We embrace new digital technologies, and are usually amongst the first few airports to use them
Innovators	We actively seek out new digital technologies and are happy to experiment with them, even when they have not been trialled much in an airport setting before

Survey question: Which of the following best describes your airport compared to other airports?

technologies that are rolled out across the entire organisation. This means that even smaller airports can be technologically advanced. Three hypotheses relating to airport characteristics are proposed as follows:

H4: Airport size has a significant direct effect on digital change.

H5: Private airport ownership has a significant direct effect on digital change.

H6: Corporatised airport ownership has a significant direct effect on digital change.

The relationships and hypotheses investigated in this study are illustrated in Fig. 1.

3. Methodology

3.1. Constructs and indicators

A survey of airport managers is used to address the research questions and hypotheses, and create key variables needed for the analysis. Based on literature reviewed in Section 2, three constructs are operationalised as components of digital change (DIG): technologies (TEC), instrumentation (INS) and data (DAT). A total of 13 indicators are used and measured on a five-point Likert scale (1 ′not at all', 2 ′to a small extent', 3 ′to a moderate extent', 4 ′to a large extent', 5 ′to a very large extent') (Table 1). Four constructs are operationalised as components of organisational readiness (ORG): clarity (CLA), collaboration (COL), capabilities (CAP) and culture (CUL). A total of 16 indicators are used and measured on a five-point Likert scale (1 ′strongly disagree', 2 ′tend to disagree', 3 ′neither disagree nor agree', 4 ′tend to agree', 5 ′strongly agree') (Table 2). Innovation (INN) is operationalised using a single question with five statements (Table 3).

A natural logarithm of the total number of passengers served is used as a proxy for airport size (PAX). Two variables are used for ownership: one for airports with a full or part-privately owned operator (PRI) and one for airports with a corporatised operator (COR). Three control variables are included to capture potential response bias: level of seniority is dichotomised as top-level manager versus other (TOP), area of work is dichotomised as digital/ICT staff versus other (ICT), number of years worked at the airport (YEA) has values of: 1 ′less than one year', 2 ′one to four years', 3 ′five to nine years', 4 ′ten to fourteen years', 5 ′fifteen years or more'.

3.2. Sample characteristics

The World Airport Traffic Report of Airports Council International (ACI, 2019) is used as a sampling frame. The 2018 report lists 2319 airports globally that serve over 1000 passengers per year. A web search resulted in finding email addresses for named managers at 262 airports (primarily the airport manager, director, CEO, or managers working in digital or ICT related areas). An invitation was sent by email to the named individual. Two repeat mailings were sent to non-respondents at two-week intervals. In addition, a link to the survey was sent via a personal message on LinkedIn to managers at 93 airports, with no repeat mailing. The survey was delivered in English and self-completed by respondents using the online survey tool Netigate. Responses were received from managers at 115 airports, out of which 94 were complete and used in the analysis. The sample size is similar to those used in other studies based on a survey of airports worldwide, for instance, 58 airports in Francis et al. (2002, 2003), 124 in Halpern and Graham (2015, 2016), 137 in Paraschi et al. (2020) and 154 in Halpern et al. (2012). Table 4 compares respondent airports to the sampling frame according to region and size of airport and provides additional sample characteristics.

3.3. Analytical approach

SmartPLS (statistical software for PLS-SEM) is used. PLS-SEM is relevant for the analysis of relationships between constructs that are created from a large number of indicators (Hair et al., 2017a; Richter et al., 2016; Sarstedt et al., 2016). In addition, PLS-SEM can be used with small samples as is the case for this study. This is because the PLS algorithm computes partial regression relationships separately instead of simultaneously, by using separate ordinary least square regressions (Hair et al., 2019a). Recommended minimum sample size depends on several factors. Assuming a commonly used statistical power of 80%, this study with six arrows pointing at the dependent variable (Fig. 6) and a desired R^2 of at least 0.25 with a 5% probability, requires a recommended sample size of at least 48 (Hair et al., 2017b). Thus, 94 observations analysed in this study is an adequate sample size.

This study uses a hierarchical component model (HCM) consisting of higher and lower-order constructs. The higher-order constructs (ORG and DIG) are comprised of reflective lower-order constructs. CLA, COL, CAP and CUL are components of ORG while TEC, INS and DAT are components of DIG. Likewise, the lower-order constructs are measured

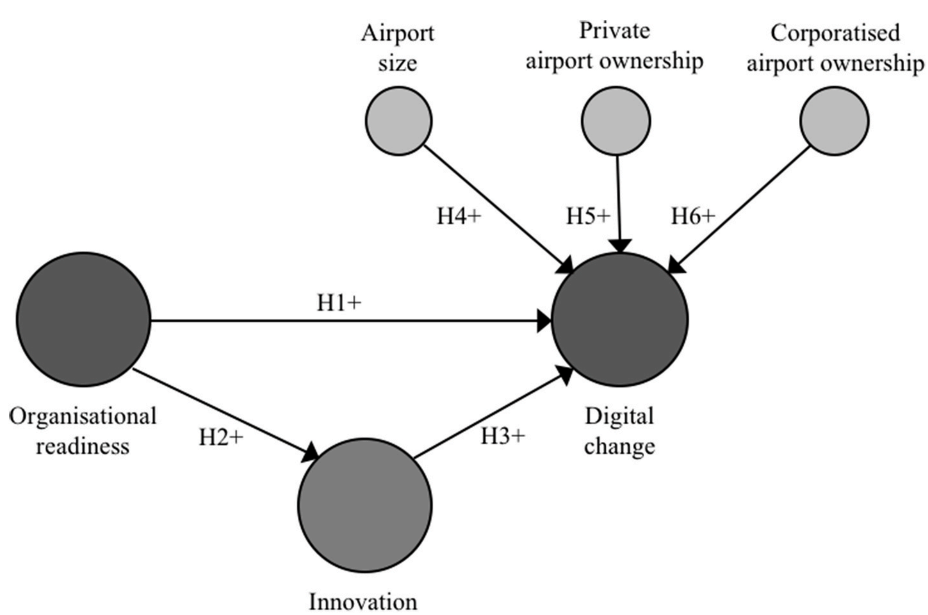

Fig. 1. Relationships and hypotheses.

Table 4
Sample characteristics.

Characteristic	Category	Respondents (R) N	Respondents (R) Percent	Sampling frame (S) N	Sampling frame (S) Percent	Difference (S-R)
Region	Africa	1	1.1	198	8.5	−7.5
	Asia-Pacific	14	14.9	798	34.4	−19.5
	Europe	43	45.7	667	28.8	+17.0
	Latin America & Caribbean	4	4.3	313	13.5	−9.2
	Middle East	4	4.3	101	4.4	−0.1
	North America	26	27.7	242	10.4	+17.2
Airport size	25 mppa or more	15	16.0	94	4.1	+11.9
	10 to less than 25 mppa	5	5.3	121	5.2	+0.1
	5 to less than 10 mppa	9	9.6	132	5.7	+3.9
	1 to less than 5 mppa	25	26.6	505	21.8	+4.8
	Less than 1 mppa	40	42.6	1467	63.3	−20.7
Ownership	Public administration	21	22.3	–	–	–
	Corporatised	51	54.3	–	–	–
	Part or full private	22	23.4	–	–	–
Seniority	Top-level manager	47	50.0	–	–	–
	Mid-level manager	38	40.4	–	–	–
	Lower-level manager	9	9.6	–	–	–
Area of work	Airport manager/Director/CEO	45	47.9	–	–	–
	Digital/ICT	18	19.1	–	–	–
	Strategy/planning/other	31	33.0	–	–	–
Years at airport	Less than 1 year	10	10.6	–	–	–
	1–4 years	33	35.1	–	–	–
	5–9 years	17	18.1	–	–	–
	10–14 years	10	10.6	–	–	–
	15 years or more	24	25.5	–	–	–

Notes: mppa is ‘million passengers per annum’. N94 for Respondents. N2319 for Sampling frame.

with indicators that are reflective, for instance, CLA1, CLA2, CLA3, CLA4 for CLA. It is therefore a reflective-reflective HCM. An embedded two-stage approach is recommended for such models (Hair et al., 2018, 2019a). In the first stage, the higher-order construct is modelled by regressing the higher-order construct on its lower-order components. Instead of interpreting the model estimates, construct scores are saved and added to the dataset as new variables (Sarstedt et al., 2019). In stage two, the new construct scores are used as indicators in the higher-order construct’s model. In stage two, INN, PAX, PRI, COR and the three control variables are also added to the model for analysis. However, two of the control variables (TOP and ICT) were non-significant and subsequently removed from the model for the final analysis.

4. Findings

4.1. Descriptive statistics

Descriptive statistics are shown in Table 5 while correlations are shown in Table 6. On average, respondents believe their organisation has a moderate level of digital change (mean of 2.80). Only four airports have a mean of four to five (Fig. 2) and all of them have means of less than 4.50. Even the most mature airports in the sample are therefore at the early stages of digital transformation. The overall picture suggests that most airports are still working on digitising or digitalising key areas (Airport 2.0 or 3.0 in terms of digital maturity) versus developing smart systems for digital transformation (Airport 4.0). Similarly, most respondents feel their organisation is in the late or early majority for innovation (Fig. 3). On average, respondents tend to agree about having an organisational readiness for digital change (mean of 3.53).

4.2. Measurement and structural model

The first stage of the analysis creates construct scores for the higher-order constructs DIG and ORG from their respective component constructs and indicators (Figs. 4 and 5). In line with Hair et al. (2018), default settings for the PLS algorithm are used but with the weighting scheme set to Factor. In terms of consistent internal reliability, Cronbach’s Alpha and loadings of individual indicators should be greater than 0.7 (Nunnally and Bernstein, 1994), while the average variance explained (AVE) should be above 0.5 for convergent validity (Fornell and Larcker, 1981). Two indicators had low outer loadings: COL4 (0.497) and CUL1 (0.593). The indicators were removed, and this resulted in an increase of AVE scores for COL and CUL from 0.708 and 0.635 to 0.887 and 0.767 respectively. Table 7 provides a summary of the final reliability and validity assessments.

Discriminant validity assesses the extent to which latent variables are distinct from one another (Hair et al., 2017b). This has traditionally been assessed using the Fornell-Larcker criterion and cross loadings (Hair et al., 2011). However, the more recently introduced Heterotrait-monotrait (HTMT) ratio is considered to be a superior approach (Henseler et al., 2015) with discriminant validity accepted when the HTMT ratio is significantly less than 1 (Sarstedt et al., 2016). Hair et al. (2019a) recommends cut-off points of 0.85 and 0.90 are acceptable. As shown in Tables 8 and 9, discriminant validity for all lower-order and higher-order constructs is acceptable. As additional checks, cross loadings confirm that each indicator has its highest loading value with the construct to which it is assigned, while the Fornell-Larcker criterion confirms that the square root of the AVE of each construct is higher than its highest correlation with any other construct.

The final model includes key constructs and control variables (Fig. 6). The PLS algorithm was run first to estimate path coefficients, R^2, effect sizes (f^2) and model fit. Bootstrapping using 5000 bootstrap resamples was then conducted to determine significance of the effects. R^2 of 0.536 for DIG means over 50 percent of the variance in DIG is explained by the model. Regarding model fit, the standardised root mean residual (SRMR) of 0.078 is within the recommended threshold of 0.08 (Henseler et al., 2016).

Significance of the path coefficients is shown in Table 10, while effect sizes are shown in Fig. 7. H1 to H4 are accepted. Effect sizes are moderate for ORG on DIG (0.185) and ORG on INN (0.340), while the effect of INN and PAX on DIG falls just short of the threshold for a moderate effect (0.134 and 0.100 respectively). H5 and H6 are rejected as their effects are not significant. The control variable (YEA) is found to have a significant direct effect on DIG (0.075) meaning that respondents that have worked at the airport for longer tend to rate their airport

Table 5
Descriptive statistics.

Label	Short description	Mean	Std Dev.	Kurtosis	Skewness
ORG	Organisational readiness	3.49	0.81	0.82	−0.92
CLA	Clarity	3.48	1.08	−0.30	0.25
CLA1	Clearly defined strategy	3.32	1.15	−0.54	−0.57
CLA2	Clear leadership	3.32	1.24	−0.83	−0.39
CLA3	Management support	3.76	1.20	−0.51	−0.68
CLA4	Clear business cases	3.53	1.14	−0.03	−0.77
COL	Collaboration	3.40	0.87	0.33	0.25
COL1	Collaborate effectively	3.48	1.08	0.05	−0.80
COL2	Channel ideas or requests	3.37	1.02	−0.01	−0.62
COL3	Learn from collaboration	3.57	1.08	0.38	−0.90
COL4	Build support	3.26	0.99	−0.72	−0.07
CAP	Capabilities	3.51	0.89	0.21	−0.60
CAP1	Knowledge	3.89	1.12	0.77	−1.15
CAP2	Skills and resources	3.52	1.06	−0.10	−0.63
CAP3	Talent	3.14	1.16	−0.78	−0.15
CAP4	Solutions that work	3.48	1.05	0.08	−0.67
CUL	Culture	3.63	0.85	0.75	−0.79
CUL1	Positive attitude	4.00	1.10	0.16	−0.95
CUL2	Dynamic approach	3.43	1.04	−0.17	−0.53
CUL3	Holistic approach	3.45	1.10	−0.16	−0.67
CUL4	Value ideas	3.65	1.05	0.04	−0.71
INN	Innovation	2.69	1.24	−0.83	0.37
DIG	Digital change	2.80	0.72	−0.52	0.10
TEC	Technologies	3.16	0.74	−0.61	−0.14
TEC1	Passenger processes	3.41	0.99	−0.81	−0.06
TEC2	Airside operations	3.15	1.00	−0.59	0.08
TEC3	Infrastructure management	2.85	0.91	−0.40	−0.30
TEC4	Resource management	2.93	0.90	−0.51	−0.29
TEC5	General administration	3.48	0.83	−0.52	0.12
INS	Instruments	2.46	0.94	−0.43	0.42
INS1	Proximity	2.29	1.04	−0.44	0.50
INS2	Pressure	2.13	1.01	−0.27	0.55
INS3	Optical	2.57	1.18	−0.66	0.37
INS4	Motion	2.86	1.14	−0.81	0.19
DAT	Data	2.62	0.93	−0.08	0.45
DAT1	Collected	3.21	1.09	−0.65	−0.19
DAT2	Analysed and used	2.62	1.05	−0.31	0.32
DAT3	Shared	2.37	1.07	−0.46	0.47
DAT4	Connected and integrated	2.27	1.08	−0.09	0.67
PAX	Passengers (million per annum)	10.24	1.83	4.33	2.25
PRI	Part or full private ownership	0.23	0.42	−0.38	1.27
COR	Corporatised ownership	0.54	0.50	−2.01	−0.17
YEA	Years at airport	3.05	1.38	−1.33	0.25

significantly higher for digital change. Also, ORG indirectly (through INN) is found to significantly affect DIG. Thus, a claim of mediation is supported. However, since ORG is also found to have a significant direct effect on DIG, it is concluded that INN has a partial mediation effect on the relationship between ORG and DIG.

5. Discussion and conclusion

5.1. Main contributions

The findings of this study show that organisational readiness has a direct effect on digital change. Therefore, supporting claims about the importance of digital congruence for digital change (Kane et al., 2016; Tabrizi et al., 2019). Considering that PLS-SEM is a component-based estimation approach, meaning that it treats all lower-order constructs as composite indicators of the higher-order constructs (Hair et al., 2019b), the findings emphasise the importance of the four components that reflect organisational readiness: (1) clarity, which includes having a clear digital strategy, a clear leadership for digital initiatives, senior management that support and engage in digital initiatives, and clear

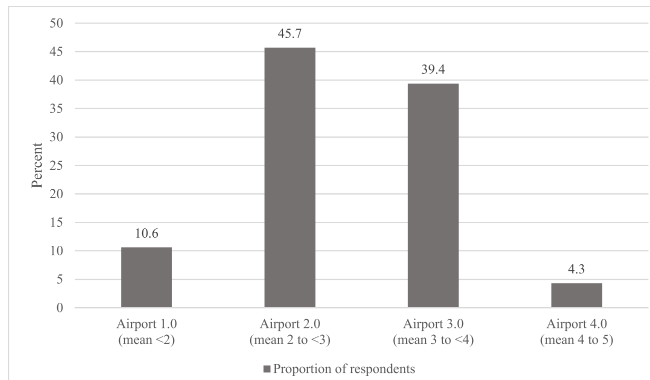

Fig. 2. Mean scores for DIG according to levels of airport digital maturity.

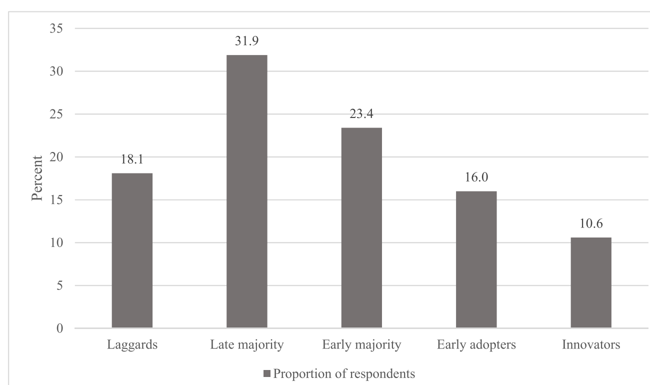

Fig. 3. Respondents according to INN.

Table 6
Correlations.

	ORG	CLA	COL	CAP	CUL	INN	DIG	TEC	INS	DAT	PAX	PRI	COR	YEA
ORG	1.00													
CLA	0.94	1.00												
COL	0.87	0.79	1.00											
CAP	0.90	0.76	0.70	1.00										
CUL	0.80	0.68	0.53	0.71	1.00									
INN	0.50	0.49	0.49	0.45	0.26	1.00								
DIG	0.55	0.61	0.53	0.45	0.28	0.64	1.00							
TEC	0.50	0.54	0.44	0.42	0.29	0.54	0.88	1.00						
INS	0.48	0.53	0.50	0.36	0.21	0.61	0.89	0.70	1.00					
DAT	0.45	0.49	0.43	0.37	0.21	0.49	0.80	0.53	0.57	1.00				
PAX	0.17	0.23	0.18	0.11	0.05	0.38	0.42	0.28	0.41	0.40	1.00			
PRI	0.14	0.17	0.16	0.15	−0.02	0.18	0.24	0.12	0.21	0.31	0.39	1.00		
COR	−0.01	0.00	0.04	−0.03	−0.05	0.20	0.08	0.13	0.09	−0.02	−0.12	−0.60	1.00	
YEA	0.02	0.06	0.02	0.00	−0.01	0.05	0.15	0.16	0.04	0.18	−0.21	−0.02	−0.04	1.00

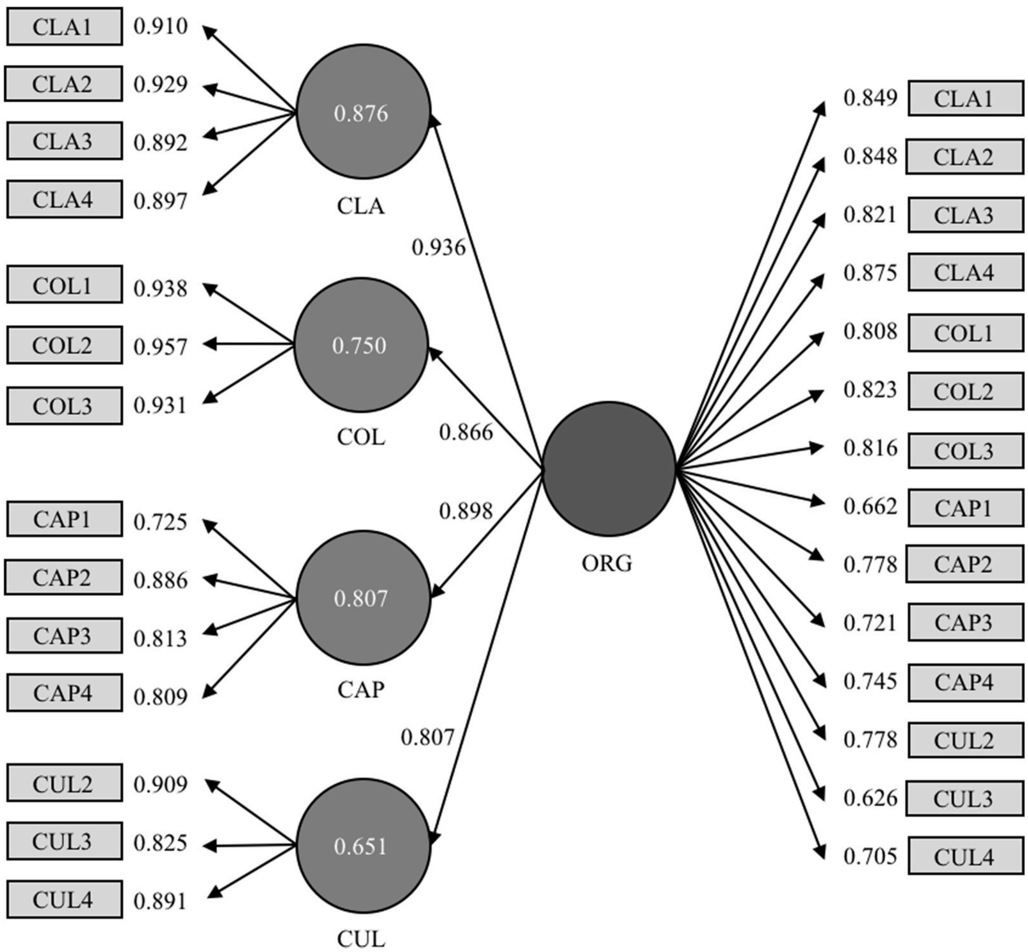

Fig. 4. Creation of component and higher-order construct scores (ORG).

business cases for digital initiatives; (2) collaboration, which includes effective collaboration with stakeholders, the channeling of ideas or requests from stakeholders, and learning from collaboration; (3) capabilities, which includes knowledge and understanding of digital technologies, the identification and anticipation of skills and resources that are needed, the acquisition and retention of talent, and the ability to build support for digital initiatives through solutions that work; (4) culture, which includes a dynamic approach to decision making, an organisation-wide approach, and a culture that recognises and values new ideas. These components were derived from anecdotal evidence of previous studies (ACI, 2017; Boutin et al., 2016; Halpern et al., 2021; Mullan, 2019; Newbold, 2020; Pell and Blondell, 2018). The findings of this study therefore provide empirical evidence of their importance for digital change.

The strongest effect in this study is between organisational readiness and innovation. Nylén and Holmström (2015) discuss managerial frameworks needed to encourage innovation and this study contributes to that literature by recognising the importance of organisational readiness. In addition, in support of Lokuge et al. (2019), innovation is found to have a partial mediating effect on the relationship between organisational readiness and digital change. This adds to a growing body of literature that explores how to derive value from innovation (Arvidsson and Mønsted, 2018; Ferreira et al., 2019; Helfat and Raubitschek, 2018), because it suggests that organisational readiness encourages digital change as a result of innovation.

Airport size has a direct effect on digital change. Previous studies have shown how digital transformation is embraced by companies of all sizes (Ferraris et al., 2018; Warner and Wäger, 2019). However, evidence from this study suggests that organisations of different sizes within the same industry, are not able to achieve the same degree of digital change. In particular, smaller airports are not able to achieve the same degree of digital change as larger ones. The effect of ownership is not significant. This means that there is no evidence to suggest that private or corporatised ownership encourages digital change. Similarly, there is no evidence to suggest that public ownership inhibits digital change.

More generally, the findings of this study contribute to knowledge on organisational readiness, innovation and digital change, establishing key constructs and indicators, and relationships between them. The focus is on airports. However, the findings have wider implications because organisational readiness, innovation and digital change are of relevance to all businesses. The study also has implications for a range of subject areas because it touches on the importance of strategy, collaboration, capabilities, culture, innovation, technologies, instrumentation and data. Researchers can use the indicators in this study as a basis for further research on scale development for organisational readiness and digital change.

In terms of managerial implications, the findings can help managers to understand organisational factors that encourage digital change. Managers can use the indicators as a basis for establishing effective monitoring and self-assessment procedures. Successful development of organisational readiness can be used to speed up the rate of innovation needed for digital change. In particular, and in support of Nylén and Holmström (2015) and Yeow et al. (2018), clarity, which is underpinned by strategy, leadership, management support and engagement, and clear business cases in this study has the highest loading on organisational readiness, and is therefore an essential requirement for managers seeking to innovate and digitally transform their airport.

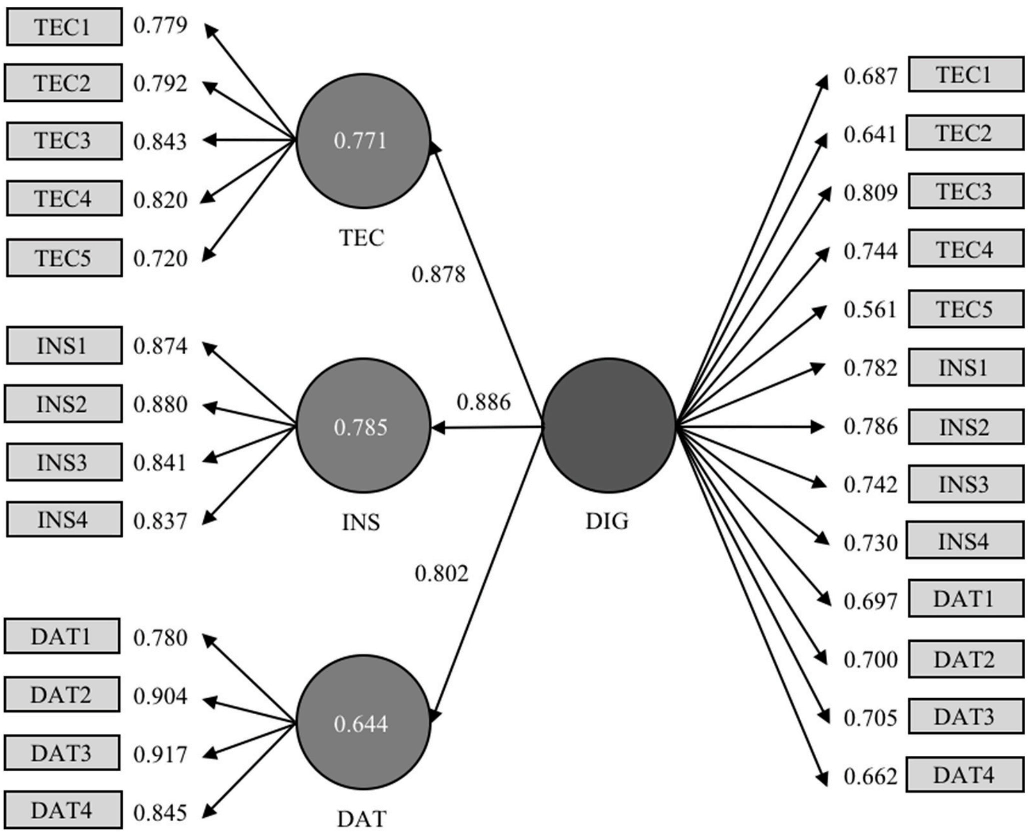

Fig. 5. Creation of component and higher-order construct scores (DIG).

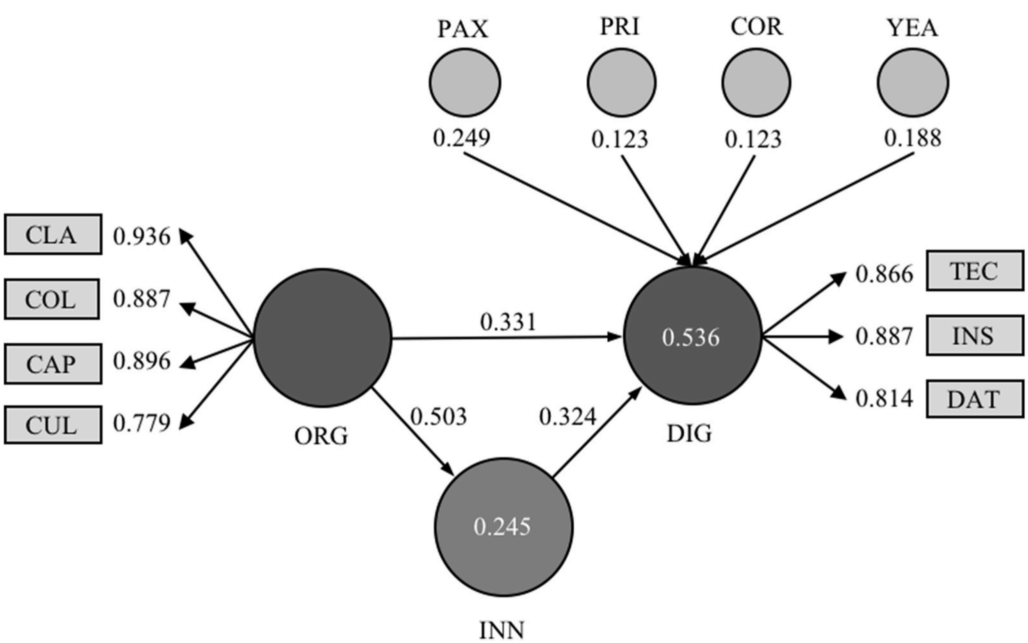

Fig. 6. Structural model with path coefficients and R^2.

5.2. Study limitations and future research

The study has several limitations and recommendations for future research. Regarding the measurement of digital change, there is no assessment of whether airports are in fact interested in digital change. There is evidence to suggest that digital change is widely embraced by airports because the indicator 'CUL1 Our organisation has a positive attitude towards digital initiatives' scored higher than any other indicator in this study (mean of 4.00, Table 5). However, the assumption that airports are interested in digital change was taken for granted. Also, the measurement of digital change focuses on technologies, instruments and data. There is no measure of the extent to which assets and physical entities such as passengers, baggage, cargo, aircraft, staff or equipment (that come into contact with technologies and instruments) are digitally

Table 7
Reliability and validity of lower and higher-order constructs.

	Cronbach's α	rho_A	Composite Reliability	AVE
ORG	0.949	0.953	0.955	0.606
CLA	0.928	0.928	0.949	0.823
COL	0.936	0.936	0.959	0.887
CAP	0.823	0.829	0.884	0.657
CUL	0.848	0.860	0.908	0.767
DIG	0.919	0.922	0.931	0.510
TEC	0.851	0.862	0.893	0.627
INS	0.881	0.882	0.918	0.737
DAT	0.884	0.885	0.921	0.745

Table 8
Discriminant validity of lower-order constructs (HTMT).

	CLA	COL	CAP	CUL	TEC	INS	DAT
CLA	–	–	–	–	–	–	–
COL	0.846	–	–	–	–	–	–
CAP	0.871	0.796	–	–	–	–	–
CUL	0.761	0.591	0.841	–	–	–	–
TEC	0.610	0.483	0.510	0.341	–	–	–
INS	0.586	0.555	0.430	0.241	0.796	–	–
DAT	0.536	0.472	0.439	0.245	0.597	0.640	–

Table 9
Discriminant validity of higher-order constructs (HTMT).

	ORG	INN	DIG	PAX	PRI	COR	YEA
ORG	–	–	–	–	–	–	–
INN	0.509	–	–	–	–	–	–
DIG	0.621	0.707	–	–	–	–	–
PAX	0.168	0.379	0.467	–	–	–	–
PRI	0.148	0.178	0.274	0.387	–	–	–
COR	0.034	0.202	0.099	0.116	0.602	–	–
YEA	0.023	0.047	0.168	0.214	0.021	0.042	–

enabled. There is no point having smart systems if assets and physical entities themselves are not digitally enabled. There are however studies that suggest a high level of digital adoption in the air transport sector, for instance, among passengers via their mobile device (IATA, 2020; SITA, 2020a). There is also a growing interest in the use of radio frequency identification (RFID), for instance, to track passenger baggage or other assets and physical entities at airports (IATA, 2017).

Regarding organisational challenges, this study considers organisational readiness, innovation, and airport size and ownership. Over 50 percent of the variation in digital change is explained by these factors. This means almost 50 percent remains unaccounted for. There may therefore be other factors that are equally or more important that have not been included in the study. Notably, governance and organisational design could be one of them, for instance, whether the organisation takes a centralised, decentralised or hybrid approach (Novacek et al., 2017). This study finds that digital change is less advanced at smaller airports. More research is needed to investigate if this is because they are less interested in digital change, for instance, because is it of less importance or value to their business, or if it is because it is more difficult for them to achieve. Either way, a better understanding is needed of the challenges faced by smaller airports and organisations in general, and how to overcome them.

This study finds that organisational readiness has a significant direct effect on both digital change and innovation, and that innovation has a significant direct effect on digital change. It also finds that organisational readiness indirectly (through innovation) has a significant effect on digital change. The mediation effect is complementary because both the direct and indirect effects are significant and positive. Following the notion that whenever there is a relationship between X and Y then there must be a mechanism that makes X lead or relate to Y, Zhao et al. (2010) argues that such a finding provides a basis for future studies to explore other hidden mechanisms besides the established mediator. Thus, the results of this study suggest that besides innovation future studies should explore other potential mediators that link organisational readiness and digital change.

There may also be moderating factors that affect the direction or strength of the relationship between organisational readiness and digital change, for instance, regarding macro or micro-environmental factors associated with the degree of market turbulence or competition faced by an airport, the legal and/or regulatory environment within which it operates (e.g. regarding government approval for the use of biometrics), or effects associated with supply and demand for new technologies (e.g. regarding access to knowledge and solutions, or market acceptance). Crises and disasters could also be added to the list. The survey work for this study finished just as the Covid-19 pandemic emerged. Prior to Covid-19, global airport investment in digital technologies was growing rapidly, for instance, from US$7.0 billion in 2016 to an all-time high of US$11.8 billion in 2019. Spend on technology as a proportion of revenue

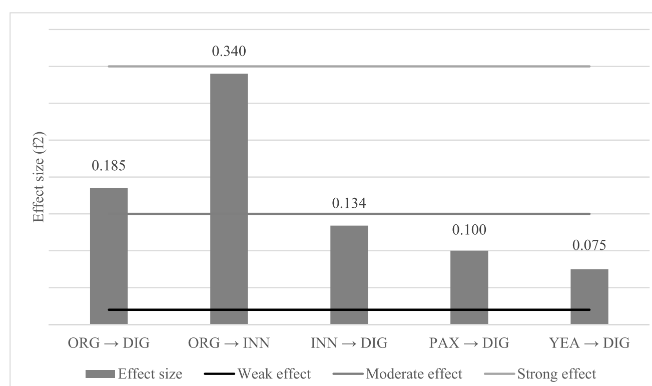

Fig. 7. Effect sizes (f^2) for significant direct effects.
Note: Threshold of 0.020 for a weak effect, 0.150 for moderate, 0.350 for strong (Cohen, 1988).

Table 10
Path coefficients and hypothesis result.

Path	Original sample	Sample mean	Std.Dev.	t statistic	p value	Hypothesis result
Direct effects						
ORG → DIG	0.331	0.329	0.074	4.445	0.000	H1: accepted
ORG → INN	0.503	0.505	0.076	6.653	0.000	H2: accepted
INN → DIG	0.324	0.328	0.083	3.894	0.000	H3: accepted
PAX → DIG	0.249	0.243	0.095	2.622	0.009	H4: accepted
PRI → DIG	0.123	0.129	0.098	1.261	0.207	H5: rejected
COR → DIG	0.123	0.122	0.091	1.344	0.179	H6: rejected
Specific indirect effect						
ORG → INN → DIG	0.163	0.166	0.050	3.264	0.001	Partial effect
Control variable						
YEA → DIG	0.188	0.185	0.076	2.465	0.014	Direct effect

increased from 4.4% to an all-time high of 6.3% over the same period (SITA, 2020b). The Covid-19 pandemic and subsequent loss of revenue will no doubt curb the growth of investment in technology at airports in the near future. However, technology is expected to play a key role in the recovery efforts of airports, for instance, with a greater focus on biometrics and seamless travel based on contactless and touchless solutions (Whitely, 2020). In addition, there is likely to be a greater focus on technologies that can facilitate cost savings or generate additional revenues given the loss of traffic at airports. Despite this, there may be moderating effects where digital change does not occur as a result of organisational readiness because the airport is exposed to the effects of Covid-19 or other crises and disasters.

Finally, data is at the heart of digital transformation, and sharing data with key stakeholders has become one of the most important tools for digital change. However, data is also a huge challenge given the siloed nature of processes and functions at airports, and the range of potential stakeholders within the airport digital ecosystem. Each stakeholder has its own responsibilities and priorities regarding data and may be inclined to protect their own interests rather than working towards a common goal. The indicator 'DAT4 Airport systems and processes that collect data are connected and integrated with those of key industry partners' scored second lowest of all indicators in this study (mean of 2.27, Table 5). Only the use of pressure sensors scored lower (mean of 2.13, Table 5). There is therefore also scope for more research on the issues and challenges associated with sharing data in airport digital ecosystems.

CRediT authorship contribution statement

Nigel Halpern: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. **Deodat Mwesiumo:** Conceptualization, Methodology, Formal analysis, Writing - review & editing. **Pere Suau-Sanchez:** Conceptualization, Methodology, Writing - review & editing. **Thomas Budd:** Conceptualization, Methodology, Writing - review & editing. **Svein Bråthen:** Conceptualization, Methodology, Writing - review & editing.

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