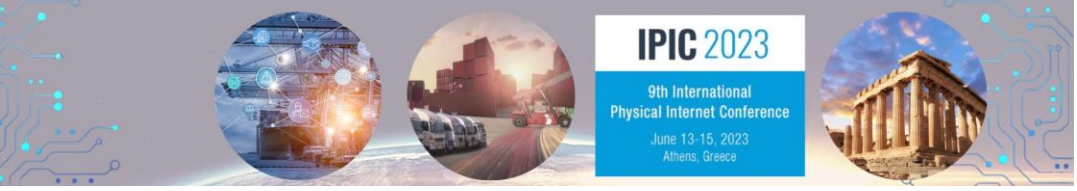

Behavioural and theoretical considerations of physical internet adoption

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Physical Internet Roadmap *(Link): Select the most relevant area(s) for your paper:☐ PI Nodes, ☐ PI Networks, ☐ System of Logistics Networks, ☒ Access and Adoption, ☒ Governance.*

1 Introduction

Physical internet (PI) is an ambitious paradigm spanning across firms, supply chains and countries to make a consolidated and interconnected network of logistics for handling goods. Ballot, Montreuil, and Meller (2014) define the physical internet as:

"A global logistics system based on the interconnection of logistics networks by a standardized set of collaboration protocols, modular containers and smart interfaces for increased efficiency and sustainability."

In a similar fashion to the actual digital internet, where all agents can be in contact with each other and exchange information and services, PI provides a collaborative decentralized environment of public and private agents to exchange logistics information and services using standard technical protocols (Nickerson and Muehlen, 2006). PI is aimed at ultimately providing the context to enable π-containers being a global and standardized loading unit; where goods irrespective of their physical characteristics can be packaged and shipped with little to no interruption to get to the destination.

In the last few years, PI has gained momentum and has grown rapidly especially in Europe (Pan, Ballot, Huang, and Montreuil, 2017) resulting into the formation of the European Technology Platform Alliance for Logistics Innovation through Collaboration in Europe (ETP-ALICE or ALICE[1]), which aligns various groups of stakeholders involved in PI. ALICE proposes five areas of development as the roadmap for PI which include technical/operational aspects of PI (i.e., "From Logistics Nodes to PI Nodes", "From Logistics Networks to Physical

[1] https://www.etp-logistics.eu/

Internet Networks", and "Developing the System of Logistics Networks towards the Physical Internet") as well as human aspects of PI (i.e., "Access and Adoption" and "Governance").

As such, there is still much room for empirical and practical studies surrounding PI (Pan et al., 2017) especially with respect to ALICE as a bold new vision for global logistics. Perhaps one of the main challenges to make PI a reality is to identify the components and necessary conditions to implement PI (Plasch, Pfoser, Gerschberger, Gattringer, and Schauer, 2021), which can be translated in wide access and adoption of PI by various logistic networks and their stakeholders. While most scientific literature on PI has been primarily focused on the technical/operational aspects of the PI (the design of modular PI loading units (Landschützer, Ehrentraut, and Jodin, 2015) and PI hubs (Ballot, Montreuil, and Thivierge, 2012; Montreuil, Meller, Thivierge, and Montreuil, 2013) among others), very few studies have so far looked into the human aspects of PI especially with respect to use, access and adoption of the PI.

The ALICE RoadMap provides a detailed plan of the milestones that will need to be achieved to implement the PI (ALICE-ETP, 2020). A range of technologies will need to be developed and adopted by various stakeholders. Models for understanding and predicting how individuals will respond to technologies will be important to construct. This will involve determining how to transform current logistics nodes and networks to more be more open and seamless. The adoption of innovative technologies such as GS1's Scan4Transport (S4T) that can provide better information about inbound and outbound flows that can reduce impediments for transhipment across modes and nodes.

To this end, in what follows we have investigated a number of major behavioral and technology-adoption theories to explore some future topics for research in the PI domain with respect to "Access and Adoption" and "Governance". The theoretical frameworks investigated in this manuscript are on individual level (e.g., Theory of Reasoned Action and Technology Acceptance Model) and firm/social level (e.g., Technology-Organization-Environment Theory and Diffusion of Innovation Theory) with each having novel propositions for future research in PI in better understanding of access and adoption of PI by individuals and across supply networks. Following our discussions of these theories, we highlight a few major topics for future research and their implications to contribute to the PI roadmap.

2 Behavioural and theoretical frameworks: Applications to PI Studies

Technology adoption and use theories are fundamentally proposed at levels of the individual and firm behaviour. At the firm level, the most well-known models are Technology, Organization, and Environment (TOE) and the Diffusion of Innovation (DOI). At individual level, Technology Acceptance Model (TAM), the Theory of Planned Behaviour (TPB), and the Unified Theory of Acceptance and Use of Technology (UTAUT) and their variations are some of the most applied models and theories in the literature for gauging user acceptance, adoption and use of the technology. We believe that in order to be able to predict the wide range adoption and acceptance of PI, researchers should consider applying these models to their empirical studies and case studies of PI adoption and report on strengths and weaknesses of PI with respect to the implications of these models. Below we briefly review the origins and main components of the aforementioned theories and their implications for PI studies.

2.1 Individual level theories

2.1.1 Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB)

Fishbein and Ajzen (1977) proposed the Theory of Reasoned Action (TRA), which posits that the intention behind an individual's action will result into the behaviour stemming from that action. In fact, one of the most basic fundamentals of technology adoption lies on individuals' intention behind adoption and use of the technology that would direct their behaviour toward that technology (Ajzen, 1991; Davis, Bagozzi, and Warshaw, 1989; Sheppard, Hartwick, and Warshaw, 1988). It is thus important to understand what variables constitute intention to predict user behaviour toward new technology. TRA suggest the following three key variables constituting intention, namely (1) attitude towards the behaviour, (2) subjective norms, and (3) behavioural intention.

Favourability or lack thereof toward a specific behaviour and its potential outcomes is referred to as "an attitude". Behavioural beliefs and the person's evaluation of outcomes of the behaviour constitute attitude. "Behavioural intention" refers to the factors motivating and influencing a certain behaviour. Naturally the stronger intentions are toward a certain behaviour, the more likely it is for the behaviour to be performed. While attitude and behavioural intention are more or less intrinsic, "subjective norms" has its roots in external factors, i.e., others approval or disapproval of behaviour that would impact whether an individual should consider performing the behaviour. Normative beliefs and motivation to comply constitute subjective norms. Thus, to summarize, TRA assesses a person's behaviour through their intention in performing a specific task. This behavioural intention in turn is affected by the person's attitude toward the behaviour and subjective norms.

Theory of Planned Behaviour (TPB) is an extension to TRA as proposed by Ajzen (1991) and includes an additional variable, namely "perceived behavioural control". Perceived behavioural control and subjective norms are shown by Ajzen (1991) to correlate significantly with behavioural intentions, further prediction consumer behaviour. Control beliefs and perceived power constitute perceived behavioural control. It has also been shown that external variables such as demographic variables, personality traits and other distinguishing personal attitudes might affect behaviour within TRA and TRB frameworks. Figure 1 below shows TRA and TPB.

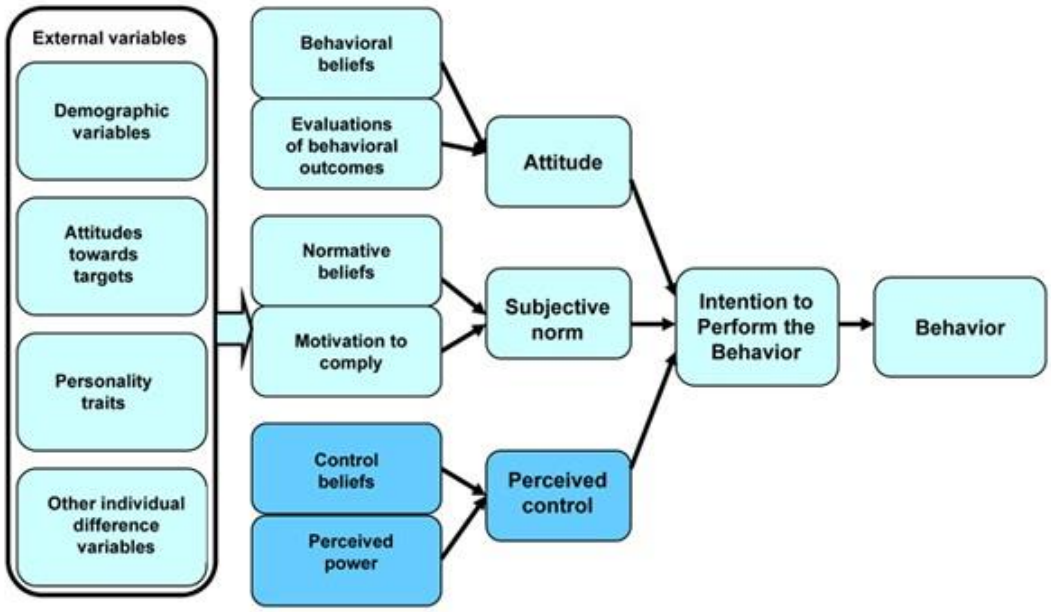

Figure 1. TRA and TPB and their variables[2]

With respect to the implications of TRA and TPB for future research in PI and ALICE's roadmap and the five areas of development for the PI, the following higher order topics can be investigated by supply chain and logistics scholars:

- *How can attitudes, subjective norms and perceived controls of decision makers in logistics networks toward PI be assessed toward their use and adoption of the PI?*
- *What subjective norms and from which stakeholders are the most influential in use and adoption of the PI?*
- *What are some external personality-related and demographic-related factors affecting use and adoption of new technologies such as the PI?*

2.1.2 Technology Acceptance Model (TAM)

Technology acceptance model (TAM) was developed by Davis et al. (1989) as an extension to TRA in the context of information technology. In this context, Davis et al. (1989) defines behavioural intention of an individual as their willingness to use the system, which is in turn based on two variables namely 'perceived ease of use' and 'perceived usefulness'. Perceived Ease of Use is the "degree to which a person believes that using a particular system would be free of effort" (Davis, 1989: 320), both physically and mentally. In other words, the less mental and physical effort is needed to use a system, the perceived ease of use will be higher. Perceived usefulness refers to how the use of the system would improve the performance of the individual in their opinion. Some components of perceived usefulness are efficiency, effectiveness, and usefulness for the job of the system. Perceived ease of used can affect perceived usefulness where a technology is easy to use then its perceived usefulness can increase for the user. Perceived ease of use and perceived usefulness according to TAM are the main determinants for use and adoption of IT.

TAM was extended later by Venkatesh and Davis (2000), known as TAM2, to include social influence (e.g., voluntariness and subjective norm) and cognitive instrumental concepts (e.g., output quality and job relevance). Variables for perceived usefulness in TAM2 are namely subjective norm, image, job relevance, output quality and result demonstrability with experiences and voluntariness being the two moderators in the model. In TAM 2, the immediate variables affecting behavioural intentions are thus subjective norm, perceived usefulness and perceived ease of use.

TAM3, suggested by Venkatesh and Bala (2008), was an extension to TAM2 and is similar to TAM2 but introduces external variables of "anchor" and "adjustment" to perceived ease of use. Variables included in anchor are computer self-efficacy, perceptions of external control, computer anxiety, and computer playfulness while variables included in adjustment are perceived enjoyment and objective usability. TAM3 is shown in Figure 2 below.

With respect to the implications of TAM and its extensions for future research in PI and ALICE's roadmap and the five areas of development for PI, the following higher order topics can be investigated by supply chain and logistics scholars:

- *How can perceived usefulness and perceived ease of use of the PI among PI's major stakeholders be assessed with respect to TAM and its extensions?*
- *What factors according to TAM3 most facilitate the adoption and acceptance of PI?*

[2] Adopted from https://www.med.upenn.edu/hbhe4/part2-ch4-figures_of_TRA-TPB.shtml

- *In addition to experience and voluntariness, do other demographic and personality trait factors affect PI adoption and use according to TAM3?*

2.1.3 Unified Theory of Acceptance and Use of Technology (UTAUT) and UTAUT2

Perhaps one of the most comprehensive technology acceptance and use is Unified Theory of Acceptance and Use of Technology (UTAUT) and UTAUT2 since Venkatesh, Morris, Davis, and Davis (2003) proposed it by comparing eight different models of technology adoption empirically and conceptually and extended it later (see, Venkatesh, Thong, and Xu, 2012) to incorporate seven variables that are linked to behavioural intention, namely (1) performance expectancy, (2) effort expectancy, (3) facilitating conditions, (4) social influence, (5) computer anxiety, (6) computer self-efficacy, and (7) attitude toward technology usage. Moderators of UTAUT and UTAUT2 are age, gender and experience. Below is a brief overview of all these main and moderator variables and their significance in UTAUT.

Performance Expectancy: is the degree to which the individual perceives the new technology helps them improve their performance. According to Venkatesh et al. (2003), performance expectancy is the strongest predictor of behavioural intention in adoption and use of a new technology.

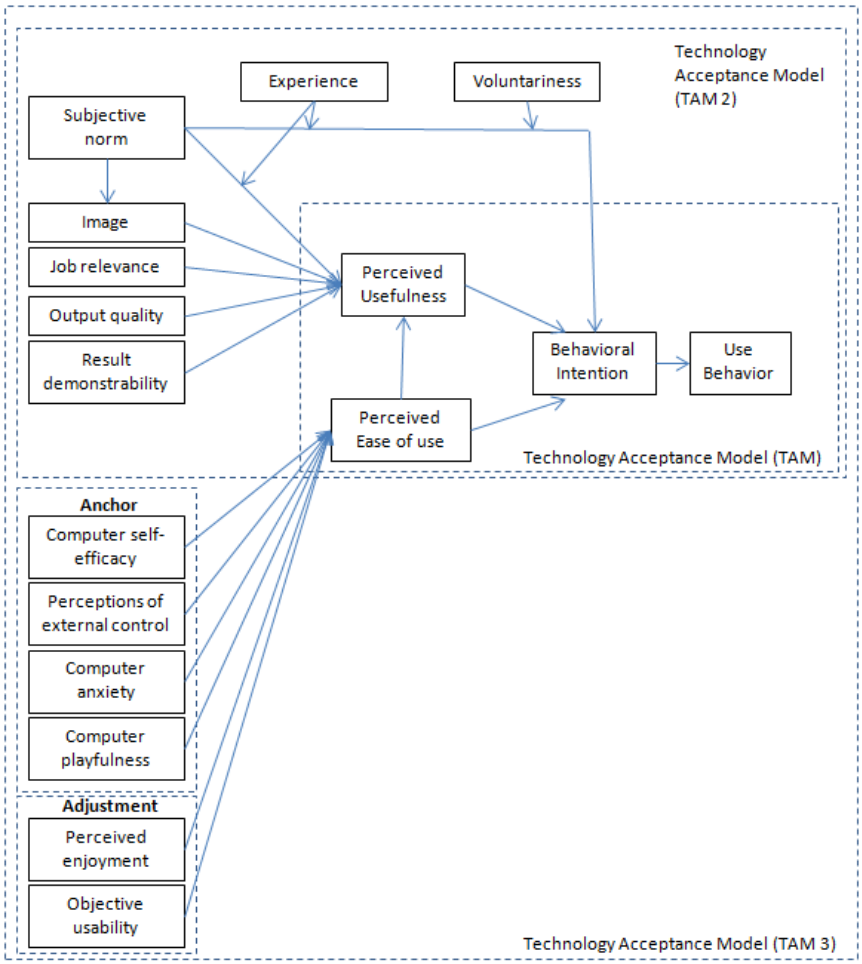

Figure 2. TAM3 and its variables adopted from Boughzala (2014)

Effort Expectancy: is "the degree of ease associated with the use of the system" (Venkatesh et al., 2003, p. 450). According to Venkatesh and Zhang (2010) effort expectancy of a particular technology has significant links with adoption of that technology.

Social Influence: is somewhat similar to "subjective norm" in TRA/TPB being "the degree to which an individual perceives that important others believe he or she should use the new system" (Venkatesh et al., 2003, p. 451).

Facilitating conditions: is "the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system" (Venkatesh et al., 2003, p. 453).

Performance expectancy, effort expectancy, social influence and facilitating conditions were the original variables proposed in UTAUT and were extended to include habit, hedonic motivation and price value later on in UTAUT2 (Venkatesh et al., 2012).

Hedonic Motivation: is "the fun or pleasure derived from using a technology" (Venkatesh et al., 2012, p. 161) and is a significant predictor of adopting new technologies such as PI.

Habit: is an automatic behaviour ensures future use of technology if the previous use of technology has already become a habit to the individual.

Price Value: is the cost to benefit ratio to the user. Figure 3 below shows the UTAUT2 model and its variables.

With respect to the implications of UTAUT(2) for future research in PI and ALICE's roadmap and the five areas of development for PI, the following higher order topics can be investigated by supply chain and logistics scholars:

- *Which of the seven main independent variables in UTAUT(2) has the most significant impact on PI adoption and use?*
- *How can PI adoption and use be improved/guaranteed through UTAUT(2)?*
- *What is the impact of age, gender and experience in use and adoption of PI according to UTAUT(2)?*

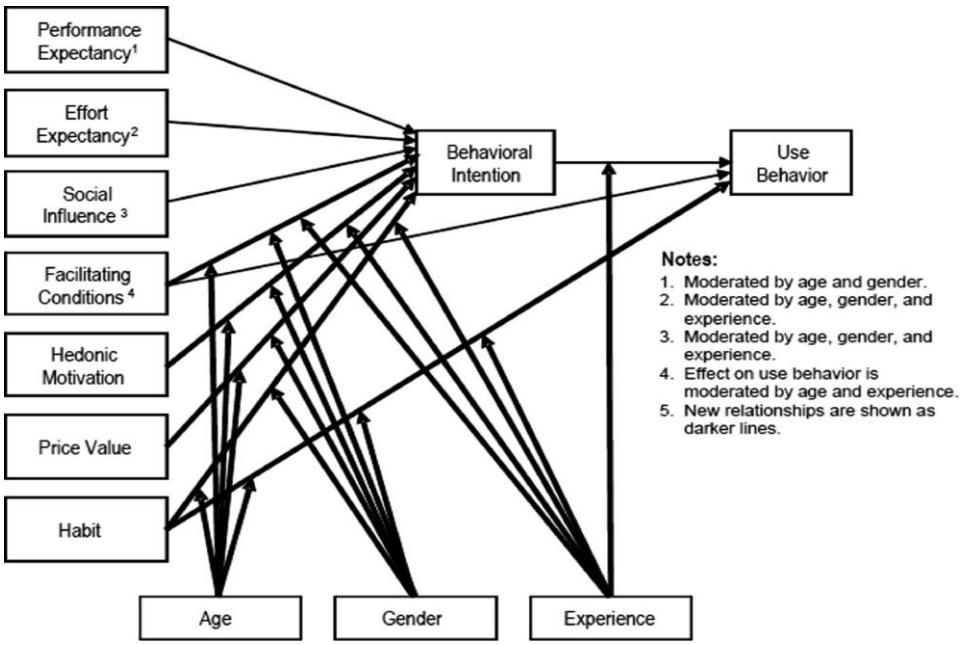

Figure 3. UTAUT2 and its variables adopted from Venkatesh et al. (2012)

2.2 Firm level theories

2.2.1 Diffusion of Innovation Theory (DOI)

The Diffusion of Innovation Theory (DOI) explains the procedure through which innovation is diffused throughout the firm (Rogers, 1983). "Diffusion" in this context is referred to the channels through which innovation is communicated with people in the firm. Also, innovation in this context is referred to any new practice, idea or an object to be adopted by the firm. In order to diffuse the innovation, one might first evaluate the innovation (technology) and its fit to the firm. To this end, Rogers (1983) proposed five attributes (variables) using which the firm can gather information on the innovation. These five attributes, as shown in Figure 4, are relative advantage, trialability, compatibility, complexity, and observability.

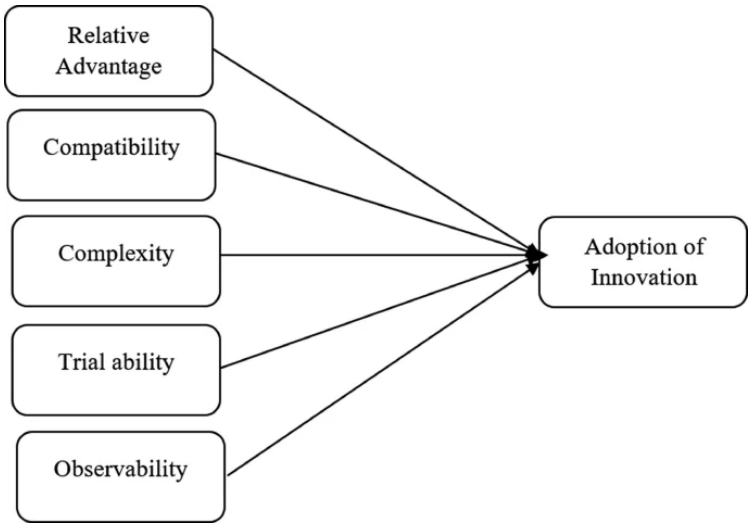

Figure 4. DOI and its variables adopted from Vatanparast (2012)

Below provides a brief overview of the five main variables in DOI (see Figure 5):

Relative Advantage: is the proportional superiority of the innovation compared to the current practices in the firm. Relative advantages is synonymous with "perceived usefulness" in TAM (Nysveen, Pedersen, and Thorbjørnsen, 2005).

Compatibility: is the extent of conformity of the innovation with existing attributes of the system including values, experiences and requirements of people who are going to adopt the innovation.

Complexity: refers to the level of difficulty adopters of innovation will face in understanding and using the new technology. Naturally there is a reverse relationship between complexity of the innovation and rate of adoption of the innovation.

Trialability: refers to the fact the chance the users might get to experiment with the innovation to a limited extent. Being able to work with the trials of the innovation can increase the rate of adoption of innovation.

Observability: refers to how visible are the outcomes of the innovation to the users. In other words the more tangible results an innovation can make, the higher should be its rate of adoption.

With respect to the implications of DOI for future research in PI and ALICE's roadmap and the five areas of development for PI, the following higher order topics can be investigated by supply chain and logistics scholars:

- *Which of the five attributes of DOI are most influential and adoption and continuous use of PI?*
- *What factors contribute to increasing relative advantage of PI, its compatibility, trialability and observability while also reducing its complexity of use among stakeholders?*
- *How can DOI be used to predict the adoption of PI in logistics networks?*

2.2.2 Technology-Organization-Environment (TOE) Framework

The technology–organization–environment (TOE), proposed by Tornatzky, Fleischer, and Chakrabarti (1990), explains the whole process of developing innovations to its adoption and implementation within firms. TOE looks into the adoption of technology from a firm's perspective and analyse the adoption decision of the firm based on the three elements of technological, organizational and external environment contexts. As can be seen in Figure 5 below, the "technology" context refers to all technologies and innovations already used by the firm and also available in the market and can be accessed by the firm that can impact decisions surrounding technological innovation in the firm. The "organization" deals with resources and characteristics with the firm such as firm size, slack resources, linking structures between employees, and communication processes within the firm. For instance, with respect to linking structures, informal linking agents (e.g., gatekeepers and boundary spanners), facilitate the adoption of innovation. Or the more decentralized the organizational structure, the more likely it is to adopt innovation. With respect to communication processes, for instance, top management's attitude and communications toward innovation can foster innovation adoption in the firm. Size can be considered as a proxy for availability of resources, and thus more slack, which can potentially increase innovation. However, the literature on slack and size so far is not quite conclusive (Baker, 2012). Finally, the "environment" context refers to factors such as presence of support infrastructure (e.g., technology service providers), regulatory environment and industry characteristics (e.g., higher levels of competition fostering more innovation) that impact technology innovation decisions of the firm.

With respect to the implications of TOE framework for future research in PI and ALICE's roadmap and the five areas of development for PI, the following higher order topics can be investigated by supply chain and logistics scholars:

- *According to TOE framework, what organizational, technological and external environmental factors have the highest influence on PI adoption and use by firms in interconnected logistics networks?*
- *With respect to external environment context according to TOE framework, which types of infrastructure should be present to ensure successful PI adoption and use?*
- *With respect to organizational context according to TOE framework, which linking structures should be present to ensure successful PI adoption and use? In the same context, would the size and slack resources of the firm matter in adoption and use of PI?*

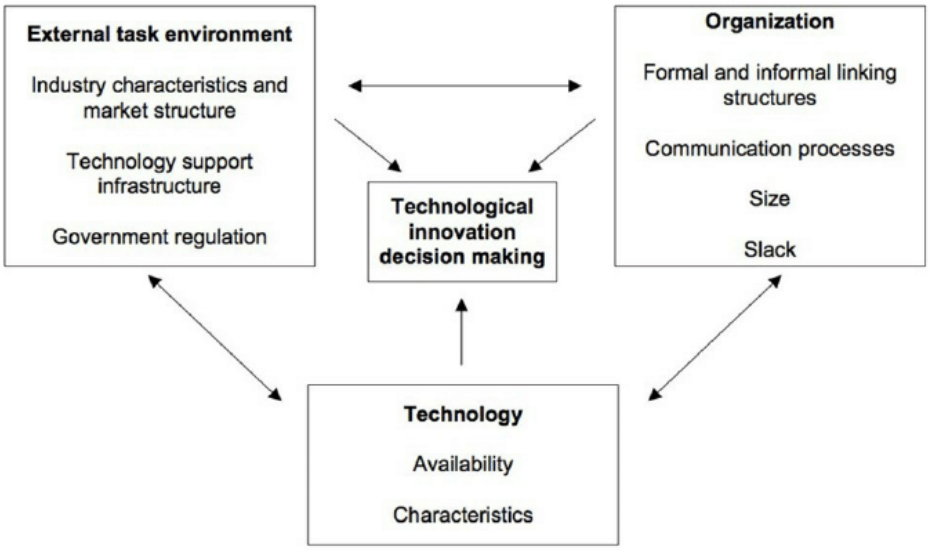

Figure 5. The TOE framework adopted from Tornatzky et al. (1990)

3 Conclusion

The current paper aimed at initiating the discourse surrounding behavioural and theoretical aspects of PI access, use and adoption. We reviewed three behavioural theories of technology adoption on individual level, namely Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB), Technology Acceptance Model (TAM1,2,3), Unified Theory of Acceptance and Use of Technology (UTAUT1,2) and two theories of technology adoption on firm level, namely Diffusion of Innovation Theory (DOI) and Technology-Organization-Environment framework (TOE) and their implications for future studies revolving around PI. While current discourse in the literature revolves primarily around technical aspects of PI implementation, we believe addressing the behavioural aspects of PI access and adoption such as behavioural intentions of adopting PI (i.e., TRA, TPB, TAM, UTAUT) as well as how PI is communicated in firms to employees (e.g., TOE) or how complex it is to use PI by people and firms (e.g., DOI, UTAUT2) could all predict the future widespread adoption of PI across logistics networks.

In fact, so far, the efforts made in the adoption of standard load units such as π containers, adopting of data standards for interchanging goods (e.g., GS1 Scan4Transport), and adoption of tracking and tracing technologies (e.g., GPS) are all steps into the right direction to facilitate technology accessibility/availability and provision of external infrastructure to consolidate logistic networks into a PI. Having said that, still much is to be learnt on how PI is perceived on individual and firm level and what is further needed to improve the perception of PI and its ease of use among various groups of stakeholders.

Perhaps one caveat of the theories reviewed in this paper is that they do not provide "an interorganizational" view of PI access and adoption. How PI would be perceived across supply chains and logistics networks would perhaps require an extension to the existing theories of technology adoption on the individual and firm level, which can be considered as a much-needed topic for future empirical studies.

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