RESILIENCE AS AN IMPERATIVE IN PUBLIC TRANSPORT ORGANISATIONS

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Abstract

This article reports on research done on resilience in urban public transport organisations. It presents the guiding principles and the framework of resilience, and the ability of public transport organisations to embed this capability. The emerging discipline of resilience studies is multidimensional and multidisciplinary. The phenomenon has been examined to present a holistic perspective on resilience through an extensive review of the literature, supplemented by empirical research in the European public transport sector. Resilience has been defined as the capacity of an organisation to survive, adapt and grow in the face of turbulent change.

The literature research produced several logical conclusions, which were reviewed by using structured interviews with a selected group of specialists in this field. This made it possible to determine guiding principles, to structure the framework and to develop a unique classification of (i) the most fundamental vulnerability factors that make an organisation susceptible to disruptions; and (ii) the capability factors as attributes required for sustained performance or accomplishment. These findings are synthesised and this research establishes the ability of public transport organisations to implement a resilience approach within the boundaries of their level of advancement and prioritised direction statements.

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1. INTRODUCTION

The role of public transport is defined in this work as being to stimulate urban, social, sustainable and economic development by transport of passengers based on their needs. Public transport operates in a dynamic environment and the concerns are sometimes shifting. Lately, discussions about pollution, the use of natural resources and more generally the sustainability of urban development have increased. In addition to the concept of sustainability, the notion of secured public transport is drawing increasing attention through many different actions ranging from strikes and technological interruptions to terrorism attacks. Various disturbances in public transport have received attention from the media, the public and policymakers. Public transport organisations are part of these dynamic environments and they need to understand how to manage disruptions both internally and in cooperation with other stakeholders. Along with the transition to more customer-focused transport, this will explain the role of public transport in society and the relevance of developing resilience in that sector. Definitions of resilience in the context of transport management are shown in Table 1.

These definitions share common elements that will be used to discuss the concept and to define resilience as the starting point for an approach to develop a framework and embed resilience in the public transport sector.

First, resilience is the concept which emphasises that *complex systems are dynamic*. A state of dynamic stability in public transport can change into a state of instability abruptly or through a gradual erosion of performance.

Second, resilience is about the ability or capacity to react or move. The focus is on *actions to deal with unexpected disruptions and/or turbulent change* and making a response to, or recovering from, a disturbance requires adjustment of the public transport organisation (or system). Public transport organisations lack both approaches to deal with disruptions (Quak, 2008; Timmer, 2008; UITP, 2008).

Third, the concept of resilience can contribute to the *adaptive process*. In this research an adaptive process includes a defensive and reactive strategy as well as a proactive one. The notion of adaptive fit presumes that a public transport organisation should invest in developing the capabilities and organisational structures needed to move to the

desired level to achieve greater immunity from fluctuation (Lengnick-Hall and Beck, 2005; Pickett, 2006; Pettit, 2008).

Finally, an organisation must assess its vulnerability across its entire environment (Ahlquist et al., 2003; Sheffi and Rice, 2005). A comprehensive solution requires a new focus on response strategies that "extends beyond the four walls of the single firm" (Christopher and Peck, 2004b). Traditional risk

management techniques lack the ability to assess the complexities of networks and chains (Slone et al., 2007). In this research the public transport organisation will be the starting point.

Analysing the definitions from Table 1 on similarities, the following definition on resilience will be used in this research: *The capacity of an organisation to survive, adapt and grow in the face of turbulent change.*

Table 1. Definitions of resilience in context of transport management

Source	Definition
Rice and Caniato (2003)	The ability to react to an unexpected disruption and restore normal operations.
Christopher and Peck (2004a)	The ability of a system to return to its original state or move to a new, more desirable state after being disturbed.
Sheffi (2007)	Containment of disruption and recovery from it.
Fiksel (2006a)	The capacity for complex industrial systems to survive, adapt and grow in the face of turbulent change.
Hollnagel (2006)	The intrinsic ability of an organisation (system) to maintain and regain stable state, which allows it to continue operations after a major mishap and/or in the presence of a continuous stress.
Center for Resilience: Ohio State University (2008)	The capacity of a system to survive, adapt and grow in the face of unforeseen changes, and even catastrophic incidents.
Pettit (2008)	The capacity of an enterprise to survive, adapt and grow in the face of turbulent change.
MIT (2008)	The ability to react to unexpected disruption and restore normal supply network operations.

2. GOAL AND OBJECTIVES OF THE RESEARCH

The purpose of this research is the development of a systematic organisational approach to create resilience within a public transport organisation through a critical revision of management practices and activities related to disruptions. The overall research goal is formulated as designing a framework to embed resilience in public transport organisations. This research goal is reached through the attainment of four objectives.

The first research objective is: *To establish the starting point(s) and limitations regarding the (re-)design of a resilient public transport organisation.* This objective entails discussing and analysing the *position* of the public transport organisation within its environment. Its position explains the *role* of public transport together with the *function* of the public transport organisation. This part of the research will be denoted as the study of *contextual resilience*. This is the property that ensures that an organisation has the capacity to identify its role and can define its function in the context of possible disturbances. This part of the research will lead to the formulation of the

first research propositions, which will be described in Section 4. Verification will take place in the subsequent steps in the research.

The second research objective is: *To structure and design a comprehensible and comprehensive resilience framework for public transport organisations.* The resilience framework will be motivated through deductive reasoning from a variety of concepts and experiences, from both the fields of risk and resilience management. The guiding principles for the resilience framework will be motivated and research propositions will be formulated. This part of the research will be referred to as the study of the *conceptual resilience framework.* This refers to the concept of deductive orientation to enable the public transport organisation to identify, assess and respond to disturbances in order to make it a resilient structure. From this a verified structure will unfold, referred to as *cognitive resilience.* This is the orientation that enables a public transport organisation to identify, assess and respond to disturbances in order to become resilient.

The third research objective is: *To identify the main elements that create knowledge about the resilience design.* This part of the research

supplements the conceptual and cognitive resilience orientation. It will discuss the main elements that determine the concept of resilience and will motivate how resilience management contributes to improved performance of the public transport organisation. The public transport organisation must be able to address issues before they become problems, and ensure that critical capabilities are available. This requires a proactive diagnostic tool to give the public transport organisation a competitive edge and move away from exclusively reactive resolutions. These embedded diagnostics can help to structure and analyse vulnerabilities and capabilities to predict and explain potential organisational behaviour. *Behavioural resilience* is the ability to use proactive diagnostics in the identification of potential vulnerability and capability factors that enable the organisation to structure and to react systematically when something unexpected occurs

The fourth research objective is: *To ensure that public transport organisations are able to make linkages between vulnerabilities and capabilities*. The ability to determine the importance, and to rank and identify critical linkages between vulnerabilities and capabilities will give the public transport organisation the possibility to derive a *balanced resilience position*.

Finally, Section 9 will reflect on the overall research goal to design and embed a structured resilience approach. It will consolidate the formulated research objectives and the knowledge produced by this research.

3. RESEARCH METHODOLOGY

The research methodology combined a literature survey, structured interviews with (50) public transport stakeholders, and a protocol-driven meeting with four public transport experts. The empirical research aims are to verify and understand the gaps between the conceptual findings from the literature and the experiences of European public transport practitioners. The processes followed for conducting empirical research include the following:

− Connected to the first, second and third research objectives, two sets of interviews are developed, needed mainly to verify and generate information on (i) the structure of the framework, on definitions, on the guiding principles of the framework; and (ii) on the content of the most important elements of the framework;

− Connected to the fourth research objective, a meeting conducted with a panel of public transport experts from different European countries is conducted to analyse critical linkages in the framework developed. Experts have been selected on the basis of expertise ranging from high expertise to strategic-level developments

and knowledge about transitions. The expert meeting was scheduled for three hours, and findings are reported as meeting results and not related to individual participants.

4. CONTEXTUAL RESILIENCE

Resilience approaches lead to a reduction in (i) problem-identification time; (ii) problem-resolution time; and (iii) response time to problems. Such approaches are basically about *building organisational capabilities* for bouncing back quickly (Sheffi, 2001). The property that ensures that an organisation has the capacity to identify its role and function in the context of possible disturbances will be referred to as *contextual resilience*.

Introducing a strategic resilience approach does not represent a sudden change of course (Booij et al., 2006). Instead, the approach focuses on a comprehensible and comprehensive attempt to significantly enhance the resilience posture of the public transport organisation currently and in the future. Contextual awareness is the starting point of the resilience approach and structure.

Awareness of resilience builds upon the *role* of public transport. Public transport organisations must take this role into account, while the *function* of the organisation is to take action if/when needed. A postulate will be formulated in the light of the literature survey that by definition is accepted to provide the necessary foundation for building on existing theory.

Postulate 1: Awareness of resilience is built on an understanding of the role of public transport in society.

This research proposition is an acknowledgement of the property of resilience, especially by higher management in public transport organisations (Christopher, 2008; Pettit, 2008; Sheffi, 2007). This awareness is the driver for understanding the forces for change, for the involvement of management, for setting priorities and proactive actions. Problems of ownership and accountability are connected to this. If disruptions are not taken into account on a higher level, that level probably also prevents commitment to analyses at the operational level, for there is no structured plan or procedure that guides such analysis or internal control. The strategic approach will enable public transport organisations to make effective and appropriate resilience-based decisions and resource allocations. As an example of a coherent approach at the strategic level, the US Transportation Security Administration (2007) defined a protection plan for transport systems, describing the set of directions (see Table 2).

Table 2. Policy statements of the US Transportation Security Administration

Management item	Directions
Mission	The Transportation Security Administration protects the Nation's transportation systems, enabling legitimate travellers and goods to move without undue fear of harm or significant disruption of commerce and civil liberties.
Vision	The Transportation Security Administration will continuously set the standard for excellence in transportation security through its people, processes, and technology.
Goals	1) Prevent and deter acts of terrorism using or against the transportation system 2) Enhance resilience of the US Transportation System 3) Improve the cost-effective use of resources for transport security

Source: Transportation Security Administration, 2007

The vision, mission and goal statements set the stage for developing specific goals and defining performance in terms of a resilience approach. Accordingly, the following research proposition (RP) is formulated:

RP 1: Contextual awareness of the concept of resilience is positively influenced by clear and consistent direction statements.

Public transport operators face a complex landscape of potential disasters, accidents and attacks. The complexity can be explained by a number of reasons. One is that the sector is composed of many different assets, links and nodes spread over a diversified spatial environment. Some assets are stationary, such as stations and infrastructure, and some are mobile, such as buses and trains, and widely distributed in time and place (Transportation Security Administration, 2007). The environment of a public transport organisation is an open, accessible, interconnected system with cross-market and cross-sector dependencies.

Understanding public transport organisations' environmental dynamics needs to be developed by looking at possible events that create unexpected changes. This entails discussing the conceptualisation of the environment. Decision makers in public transport organisations must align their organisation to the changed environment in order to achieve a strategic fit that creates opportunities and also addresses threats to the organisational resources (Ploos van Amstel, 2002). According to Arminas (2003), awareness is enhanced when managers understand the business context they operate in and the strategic goals they focus on. Because of the implications and the cascading effects resulting from triggering events, it is important for the public transport organisation to structure and analyse its environment. The following research proposition is, therefore, formulated:

RP 2: Contextual awareness of the concept of resilience is positively influenced by a clear environmental focus.

In the contingency approach the relation between organisation and environment is central, but the importance of a fitting internal structure is also considered relevant. If top management does not take responsibility, processes and procedures might be introduced only after devastating consequences have been unleashed (Zsidisin et al., 2004). A *systematic organisational approach* needs to be structured and tuned for internal consistency as well as external consistency with the environment. The two research propositions presented thus far are directly related to the object of experience. From the object of management science, two further research propositions will be added.

To improve decision making and performance, a decision-making process is needed (Ploos van Amstel, 2002). In order to have a formal resilience process and procedure in place, there should be a clear understanding of responsibilities (RACI, 2009). The concepts of responsibility and accountability are not addressed frequently in the resilience management literature (Booij et al., 2006). The following research proposition is, therefore, formulated:

RP 3: Contextual awareness of the concept of resilience is positively influenced by clear lines of responsibilities.

Identification, assessment and response analysis depend on expert judgement, field findings and information. In turn, the assessments should provide reliable information on probability and impacts (Kleindorfer and Saad, 2005). This means that data used for analysis should be reliable, because no tool or analysis method can turn unreliable data into reliable information. Collecting data is a collective effort and will in addition demand some action on verifying, updating and protecting data. Real-time sharing of correct information within the public transport organisation and between its stakeholders and partners is essential to maximise responsiveness and flexibility of response (Blackhurst et al., 2005). The following research proposition is, therefore, formulated:

RP 4: Contextual awareness of the concept of resilience is positively influenced by reliable information.

The first research objective is formulated as: "To establish the starting points and limitations regarding the (re-)design of a resilient public transport organisation". The development of this concept of a contextual awareness of resilience has now met this first research objective.

5. CONCEPTUAL RESILIENCE FRAMEWORK WITH GUIDING PRINCIPLES

This section will discuss the link between contextual awareness, disruption analysis and vulnerability. Smallman (1996: 12) notes that "the operating environment for many companies has become unpredictable. Many managers accept that *instability and disruption management* is becoming an increasingly common term in business life." From the considerable amount of literature it can be concluded that awareness of the concept of resilience, as described in Section 4, has increased a focus on, and confirmed the need to, analyse disruptions (Pettit, 2008; Sheffi and Rice, 2005; Zsidisin et al., 2004). These reviews lead to the following research proposition:

RP 5: A higher level of awareness on resilience has a positive effect on the level of identification and assessment of disruptions as forces for change.

Public transport disturbances can be highly diverse and different in time, but they all result in some more fundamental forces of change. Comparing events where considerable historical and scientific data exist (e.g. accidents, natural disasters) to those where there is greater uncertainty and ambiguity (e.g. terrorism, theft, climate change), there is a much greater degree of "discomfort" in undertaking traditional risk assessments and a greater need to assess and structure *fundamental* factors that make an organisation susceptible to disruptions. Resilience has been defined as the capacity of an organisation, in this case the public transport organisation, to survive, adapt and grow in the face of turbulent change. Based on the literature search, two constructs are assumed to be relevant: vulnerability and capability.

To begin with, a resilience framework builds upon the basic concept of vulnerability, defined as: *fundamental factors that make an organisation susceptible to disruptions.* The framework for resilience must take into account those fundamental factors that encompass the broadest possible range of disruptive threats (Fiksel, 2006b; Pettit, 2008). Disruption identification and assessment will be referred to as *disruption analysis*. The disruption

analysis is the source of defining the *forces of change*, as well as defining vulnerabilities as fundamental factors. This leads to the following research proposition:

RP 6: Forces for change create vulnerabilities.

Based on the previous two research propositions, the following partial structure of the framework will emerge, dealing with the link between awareness, management control activities and capabilities. Referring to the previously mentioned literature, the link between awareness and management control can be supported. The awareness will induce the organisation to take action as a reactive and as a proactive activity. These reviews lead to the following research proposition:

RP 7: A higher level of awareness has a positive effect on internal control.

Capabilities are described as attributes that enable an organisation to anticipate and overcome vulnerabilities. These capabilities could prevent actual and future disruptions (e.g. security measures deterring a terrorist attack), mitigate the effects of a disruption, or enable adaptation following a disruption (e.g. the development of new products or services, or entering a new market) (Pettit, 2008). Concepts such as flexibility, agility, adaptability and visibility are some of the commonly discussed managerial capabilities (Lee, 2004). The literature suggests many different types of capabilities (Fiksel, 2003; Hamel and Valikangas, 2003; Rice and Caniato, 2003; Peck, 2005; Sheffi, 2007).

To counteract vulnerabilities, this research has shown that organisations can develop capabilities that assure short- and long-term survival. Internal control factors create capability attributes as fundamental attributes or characteristics. Capabilities have been defined as *attributes required for performance or accomplishment*. This will lead to the following research proposition:

RP 8: Internal control creates capabilities.

The framework connects awareness to vulnerabilities through internal control. The resilience framework is based on the link between the two proposed constructs: vulnerability and capability. The scope of the framework should encompass all processes, relationships and resources that offer capabilities to overcome vulnerabilities. The essence of resilience lies in this. This leads to the next research proposition:

RP 9: Resilience increases as capabilities increase and/or vulnerabilities decrease.

Balanced resilience will result from a fit between the vulnerability and the capability factors. The public transport resilience framework must deliver potential for providing public transport management with insight into its strengths, weaknesses and priorities. The framework needs to provide guidance to develop a strategy for improving the level of resilience, to focus on resource investments to fill gaps, and to weigh such investments against the potential returns. Periodic assessment of resilience is necessary in a turbulent environment, and the organisation that does so realigns its resources faster than its rivals (Hamel and Valikangas, 2003; Brechbuhl, 2007). A balanced result will improve the organisational performances. A variety of organisations discussing the agile and resilient enterprise at the Tuck School of Business, Dartmouth, in 2007 confirmed this relation (Brechbuhl, 2007). A balanced resilience will take into consideration all direction statements and all organisational levels. From this the following research proposition is formulated:

RP 10: Performance improves when capabilities and vulnerabilities are balanced.

With the research propositions formulated in the preceding parts of the development of a conceptual resilience structure, the resultant framework is presented in Figure 1.

**Figure 1.** Resilience framework: Connecting to performance
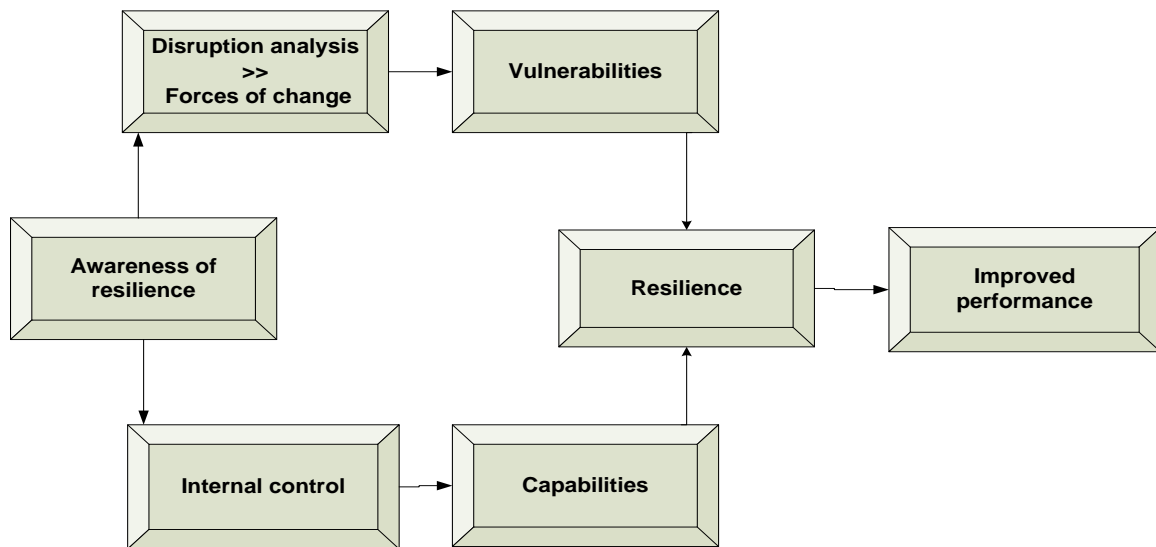
Measurement of vulnerabilities and capabilities can provide an evaluation of the current level of resilience, and it is, therefore, a tool to direct improvements and for knowledge development. The literature notes that awareness itself is positively influenced by the negative consequences of disruptions, delays and failing control. This awareness reflects on external and internal disruptions. Experiencing the consequences of disruptions can have a significant impact on organisational awareness. Research on social amplification confirms that an adverse event results in a large increase in the perception of disruptions within a company (Smallman, 1996).

The literature and the risk and resilience approaches indicate that the recognition of feedback loops is relevant. In this research the assumption is that the improved performance will have a higher impact on awareness as a feedback mechanism than the disruption analysis itself. The following research proposition is formulated:

RP 11: Improved performance will have a positive feedback effect on creating awareness of resilience.

The developed conceptual resilience framework for public transport organisations is shown in Figure 2.

Figure 2. Conceptual resilience framework
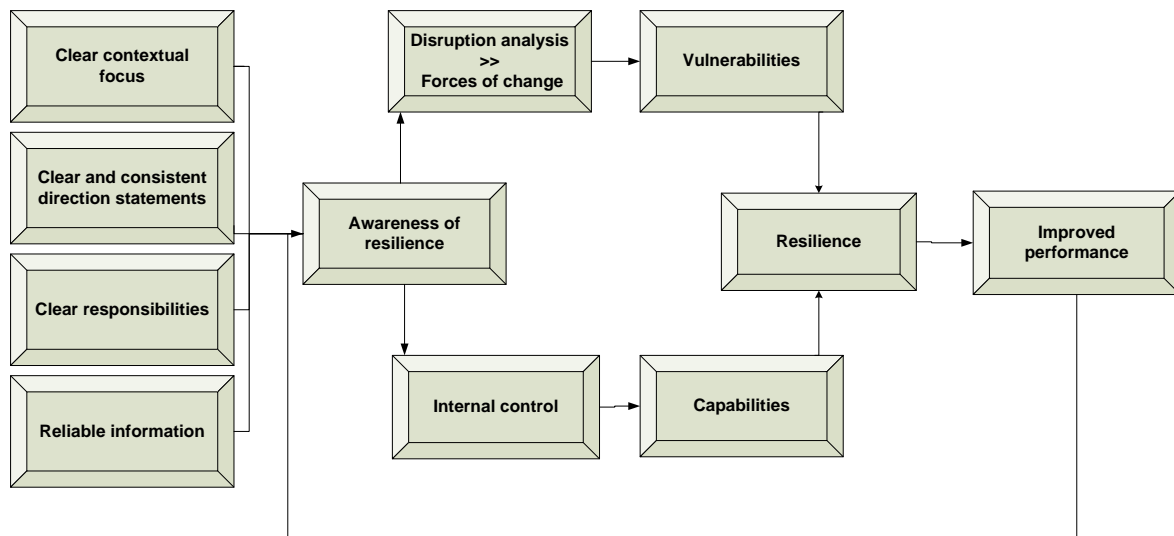
6. COGNITIVE RESILIENCE

This section addresses the second research objective: To structure and design a comprehensive and comprehensible resilience framework for public transport organisations. Research propositions have been formulated in the previous sections and a conceptual resilience framework has been motivated based on deductive reasoning. The purpose of this section is to assess the results of the developed conceptual framework to ascertain its fit with the empirical situation.

Overview of vulnerabilities and capabilities: In the interviews, public transport organisations provided input on vulnerability and capability sub-factors. The term *sub-factors* is used to make a distinction between these and fundamental factors. In the next section the content of the concepts *vulnerability* and *capability* will be discussed and an overview of the recognised sub-factors will be presented. From the discussions it became clear that the public transport organisations were not able to present a list of vulnerabilities and capabilities that is structured, complete or can be fully motivated.

Level of awareness: During the empirical phase of the research it was observed that public transport organisations are in the process of understanding the need to increase the awareness of disruptions and internal control, but have not yet adopted a holistic approach.

Level of approach: The proposed framework and the associated definitions pose challenges that are both conceptual and practical. These include discussions on defining levels of resilience (Hollnagel, 2006). In this part of the research the evidence gap is addressed to the *level of the public transport organisation*. Resilience approaches have also emphasised other managerial levels. Resilience can also be *division or activity-level-focused*. In public transport this implies adopting a different approach to resilience in different entities; for example one in rail operations and another for bus operations. Findings show that some public transport organisations have taken their approach to disruption and mitigation in that direction, but mostly without adopting a systematic organisational or corporate-level approach. There was no evidence of collaborative cross-checking of events as a critical component of resilience. This aspect is recognised in the literature as a complex element in the resilience approach (Patterson et al., 2007).

The discussions to develop a resilience approach resulted in two different views. Some agreed about starting with an *organisational-level approach*. Others suggested starting by defining the vulnerabilities and associated capabilities first to the *activity level* – what is required within legal structures and compliance agreements – and from that starting point developing to the next (second) level towards an organisational-level approach. From a knowledge-acquisition point of view, first experiences can be obtained by starting at the activity level, but with the clear aim of developing a systematic organisational approach. All participants also agreed that this network cooperation is the next (third) level of advancement after the organisational introduction and implementation of resilience. A truly resilient system should be able to survive, adapt and grow at all three levels.

Knowledge of advantages and complications: Concerning the introduction of the framework, public transport organisations are aware of the major advantages and complications of a structured resilience approach. Table 3 presents an overview without an order of priority and without implying any direct relations between the two parts.

Table 3. Overview of advantages and complications of resilience approach

Advantages	Complications
Structured improvement of monitoring events	Priority on the strategic level: - lower awareness of resilience
Introducing of scripts with less dependence on expertise of individual persons	Cost–benefit ratio difficult to determine: - visibility of core business
Better alignment to tender contracts and external and internal compliances: efficiency and effectiveness	Responsibilities and available information: - no communication structure for risk and resilience - fear of bureaucracy
Coordination within the public transport sector to enhance the level of knowledge	Human resources: - lack of content expertise - lack of understanding of the concept of a structured approach
Consistency and completeness, and less redundancy: efficiency	Approach must not look academic: - no structured best practices available
Shorter time to act: learning organisation	Low level of cooperation between public transport organisations
Balanced structure of capabilities to vulnerabilities to deal with over- and under-reactions	No structuring from legal or contracts (tenders) requested
Better prepared for the unforeseeable	Connection to existing security and risk structures

It can be deduced that public transport organisations have not given priority to the introduction of a structured approach, but are aware of possibilities and the needs of the future. However, it can be concluded that the concepts and definitions, guiding principles and structure of the framework have been acknowledged. With this the orientation that enables an organisation to identify, assess and respond to disruptive events has been developed. This will be referred to as *cognitive resilience*. This section has presented discussions on research propositions and the connected relations of the framework structure together with the modifications, which results in the following adapted structure (Figure 3).

Figure 3. Verified resilience framework for public transport organisations
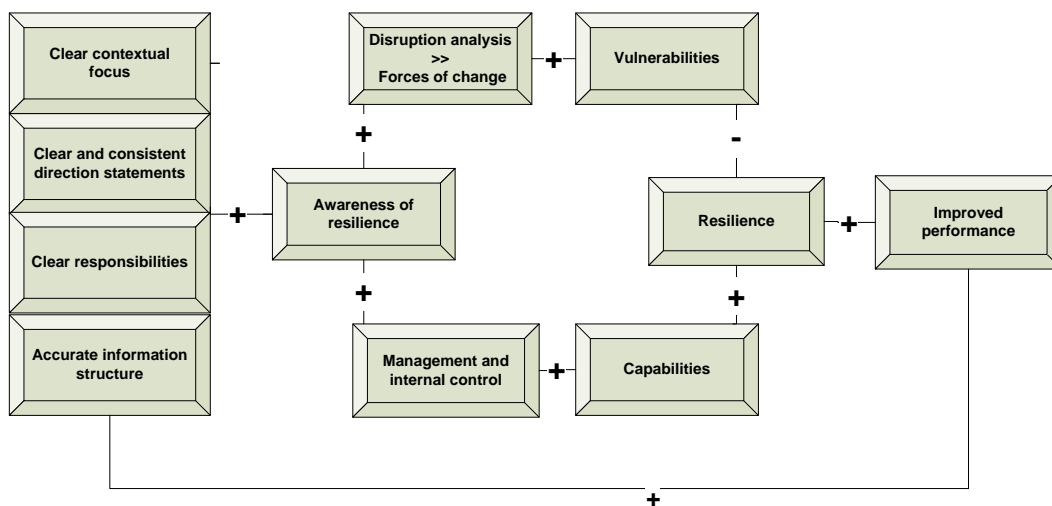
The second research objective has been achieved by discussing both the concepts of *contextual resilience* and *cognitive resilience* as providing the conceptual orientation that enables an organisation to identify, assess and respond to disruptive events.

7. BEHAVIOURAL RESILIENCE

The third research objective is: To identify the main elements that create knowledge about the resilience design. This section will first discuss the *fundamental* factors that make an organisation susceptible to disruption. Next, the *attributes* required for performance and accomplishment will be considered.

The starting point in this part of the research is the studies of the Center for Resilience (2008) and the study by Pettit (2008), which identified sources of forces of change in the field of logistics. The Center for Resilience defined six such sources and the study

by Pettit seven. There is a great degree of overlap between them. From these lists seven categories of vulnerabilities are identified: turbulence; deliberate threats; external pressures; resource limits; sensitivity; connectivity; and supplier/customer disruptions. The last one was not identified by the Center for Resilience.

Table 4 provides an overview of organisational vulnerability factors with descriptions and sub-factors. Because this list will be discussed with practitioners from public transport organisations for verification as well as to generate new information, it is referred to as "Vulnerability factors with description and sub-factors", while the list after the empirical research (Table 6) will be referred to as "Vulnerability (sub-)factors after verification".

Table 4. Vulnerability factors with description and sub-factors

Vulnerability (Exposure to factor) (Predominantly based on structure of Pettit, and the Center for Resilience)	Description (Predominantly based on Pettit, and the Center for Resilience)	Sub-factors Descriptors (not exhaustive) from literature, Global Risk Report of World Economic Reform, and from interviews with public transport organisations
Turbulence, accidental	Environment characterised by changes in external factors beyond internal control	Natural disasters (floods, earthquakes) Health disasters, pandemics Geopolitical disruptions Unpredictability of markets Unforeseen technology and IT failures Fluctuation in financial issues
Threats, intentional	Deliberate attacks aimed at disrupting operations or causing human or financial harm	Terrorism and sabotage (internal, external) incl. cyber-disruption, piracy and theft and espionage Media pressures, offensive advertising, brand attacks Labour disruptions, union activities, strikes Special interest groups
Pressures, external	Influences not specifically targeted at the public transport organisation that create business constraints or barriers	Competitive innovation Social/cultural changes Political/regulatory change Price pressures (competitive) Environmental, health, safety concerns Corporate responsibility concerns
Resource limits	Constraints on output and productivity based on availability of connected factors of production	Natural resources Intellectual property Supplier and utilities availability Asset utilisation Distribution availability Data-storage capacity Human resources
Sensitivity	Relevance of carefully controlled conditions for product, service and process integrity and liability	Complexity of design and product purity Complexity of process operations Consumer requirements for quality Restricted utilisation of materials and data Reliability of (key) equipment and IT Potential safety hazards Loss of key personnel Visibility of disruption to stakeholders Symbolic profile of brand Concentration of capacity
Connectivity	Degree of reliance and interdependencies on outside entities	Scale/extent of (travel and traffic) networks Degree of outsourcing Information interdependence and reliance Reliance upon specialty sources and information flows
Supplier/customer disruption	Susceptibility of suppliers and customers to external forces or disruptions	Supplier trust and reliability Customer and loyalty relations External relations Reliability of relations

The vulnerabilities (shown in Table 4) must be counterbalanced with managerial controls that create capabilities. Pettit defined 14 capabilities; the Center for Resilience identifies 16. To start this capability identification process, the shorter list is chosen based on the arguments of the participants of the interviews on managerial challenges. This list identified: flexibility in sourcing; flexibility in order fulfilment; capacity; efficiency; visibility; adaptability; anticipation; recovery; dispersion; collaboration; organisation; market position; security; and financial strength. (The Center for Resilience identifies, in addition, flexibility in manufacturing; and product stewardship.) These capabilities are described in Table 5. Because this list will also be further discussed with practitioners from public transport organisations for verification as well as to generate new information this list is referred to as "Capability factors with description and sub-factors" while the list after the empirical research will be referred to as "Capability (sub-) factors after verification".

Table 5. Capability factors with description and sub-factors

Capability factors **Structure (predominantly based on Pettit, and the Center for Resilience)**	*Description* **(predominantly based on Pettit, and the Center for Resilience)**	*Sub-factors* **Descriptors (not exhaustive) from literature, the Global Risk Report of World Economic Forum, and from interviews with public transport organisations**
Flexibility	Ability to change quickly	
Flexibility (in sourcing)	Ability to quickly change *inputs* or the mode of receiving inputs	Modular product design Standardisation and commonality of parts Multiple sources Contract flexibility with suppliers
Flexibility (in order fulfilment)	Ability to quickly change *outputs* or the mode of delivering outputs	Alternative transport and distribution offering Multiple service centres Update of information Postponement
Capacity	Availability of *assets* to enable sustained production or service levels	Utilities back-up sources Asset reserve capacity beyond normal deviations Labour capacity flexibility Communication and IT back-up systems
Efficiency	Capability to produce outputs with minimum resource requirements	Waste elimination Labour productivity Asset utilisation Quality management/service variability reduction Failure prevention Process standardisation Preventive maintenance
Visibility	Knowledge of the status of operating assets and the environment	Business intelligence gathering Information/automation technology Status of all personnel Market visibility, external monitoring Service and equipment visibility People visibility
Adaptability	Ability to modify operations in response to challenges and opportunities	Learning from experience/feedback mechanism Strategic simulation Alternative technology development Fast re-routing and re-scheduling Seizing advantages from disruptions Product life cycle management
Anticipation	Ability to discern potential future events or situations	Monitoring early warning signals Forecasting (horizon) Deviation and near-miss analysis Preparedness planning Business continuity planning Emergency preparedness Government lobbying
Recovery	Ability to return to normal operations state rapidly	Crisis management Equipment reparability Resource mobilisation Communication strategy Mitigation processes
Dispersion	Broad distribution of assets	Asset and key resources decentralisation

		Distributed decision making
		Dispersion of markets
		Location-specific empowerment
Collaboration	Ability to work effectively with other entities for mutual benefit	Disruption sharing with partners
		Supplier relations management
		Client and customer relations management
		Collaborative forecasting
		Information and communications exchange
Organisation	Human-resource structures, policies, skills and culture	Empowerment
		Creative problem solving
		Accountability including reporting
		(Cross-) training and workforce flexibility
		Culture of caring
Market position	Status of organisation or its product/services in specific markets	Product positioning
		Market share
		Brand equity
		Customer service management
		Sustainable position
		Customer loyalty/retention
Security	Defence against deliberate intrusion or attack	Access restrictions
		Employee involvement
		Collaboration with governments
		Personal security
		Cyber-security
		Layered defences
		Information pooling
Financial strength	Capacity to absorb fluctuations in cash flow	Financial reserves and liquidity
		Price margin
		Insurance
		Portfolio diversification

Service providers such as public transport organisations cannot keep an inventory of their product. Consequently, an operation-related disruption will lead to an immediate service failure, unless there is extra capacity or some other redundancy or flexibility. Ultimate *flexibility* means having variable alternatives in any situation. Standardisation of material, processes and information creates options for interchange abilities as well as for when there is a shortfall. Shifting public transport services from one disrupted facility to an alternative requires not only the ability to shift, but also the ability to provide a service from that alternative facility.

Proactive diagnostics help to structure and analyse vulnerabilities and capabilities in order to predict and explain potential organisational behaviour. Such a proactive approach puts the organisation at an advantage by moving beyond reactive resolutions. *Behavioural resilience* is the ability to use proactive diagnostics in the identification of potential vulnerability and capability factors that enable the organisation to respond in a systematic way when something unexpected occurs.

Three major dimensions of resilience are relevant:
– Resilience is the capacity to prevent a bad occurrence
– Resilience is the capacity to prevent a bad occurrence from worsening
– Resilience is the capacity to recover from a bad occurrence

Regarding the concepts of vulnerability and capability as determinants of resilience, participants of the meeting convened as part of the empirical research phase all agreed on the following:
– Descriptions of vulnerability factors are clear
– Descriptions of capability factors are clear
– Participants described lists of vulnerability and capability (sub-)factors as comprehensive, complete and applicable to the sector, and agreed that the discussed framework is in principle applicable in public transport organisations. All participants agreed on the descriptions of the vulnerability and capability factors, and regarded both lists as complete and comprehensive.

The discussions led to the vulnerability and capability lists (Tables 6 and 7).

Table 6. Vulnerability (sub-)factors after verification

Vulnerability (exposure to factor)	Description	Sub-factors Descriptors (not exhaustive) after verification
Turbulence, accidental	Environment characterised by changes in external factors beyond internal control.	Natural disasters (floods, earthquakes) Health disasters, pandemics Geopolitical disruptions Unpredictability of markets Unforeseen technology and IT failures Fluctuation in financial issues
Threats, intentional	Deliberate attacks aimed at disrupting operations or causing human or financial harm.	Terrorism and sabotage (internal, external) incl. cyber-disruption, piracy and theft and espionage Media pressures, offensive advertising, brand attacks Labour disruptions, union activities, strikes Special-interest groups
Pressures, external	Influences, not specifically targeted at the public transport organisation that create business constraints or barriers.	**Related to public bodies:*** Political/regulatory change (including tariff) **External inspections:*** Environmental, health, safety concerns **Related to all other than public bodies:*** Competitive innovation Social/cultural changes Price pressures (competitive) Corporate responsibility
Resource limits	Constraints on output and productivity based on availability of connected factors of production.	Natural resources Intellectual property Supplier and utilities availability Asset utilisation Distribution availability Data storage capacity Human resources **Finite funding.***
Sensitivity	Relevance of carefully controlled conditions for product, service and process integrity and liability.	Complexity of design and product purity Complexity of process operations Consumer requirements for quality Restricted utilisation of materials and data Reliability of (key) equipment and IT Potential safety hazards Loss of key personnel Visibility of disruption to stakeholders Symbolic profile of brand Concentration of capacity
Connectivity	Degree of reliance and interdependencies on outside entities.	**Outside entities in general:*** Scale/extent of (travel and traffic) networks Reliance upon specialty sources and information flows Reliability of external relations **Net activity related outside entities:*** Supplier trust and reliability Degree of outsourcing Information independence and reliance Customer and loyalty relations

* Sub-factors in bold are changes compared to the initial lists.

Table 7. Capability (sub-)factors after verification

Capability factors	Description	Sub-factors (not exhaustive) after verification
Flexibility	Ability to change quickly.	
Flexibility in sourcing	Ability to quickly change *inputs* or the mode of receiving inputs.	Modular product design Standardisation and commonality of parts Multiple sources Contract flexibility with suppliers
Flexibility in order and demand fulfilment	Ability to quickly change *outputs* or the mode of delivering outputs	Alternative transport and distribution offering Update of information Multiple service centres Postponement
Capacity	Availability of **assets** to enable sustained production or service levels.	Utilities back-up sources Asset reserve capacity beyond normal deviations Labour capacity flexibility Communication and back-up IT systems
Efficiency	Capability to produce outputs with minimum resource requirements.	Waste elimination Labour productivity Asset utilisation Quality management/service variability reduction Failure prevention Process standardisation **and optimisation*** Preventive maintenance
Visibility	Knowledge of the status of operating assets and the environment.	Business intelligence gathering Information/automation technology Status of all personnel Market visibility, external monitoring Service and equipment visibility People visibility
Adaptability	Ability to modify operations in response to challenges and opportunities	Learning from experience/feedback mechanism Strategic simulation Alternative technology development Fast re-routing and re-scheduling Seizing advantages from disruptions Product life cycle management
Anticipation	Ability to discern potential future events or situations.	Monitoring early warning signals Forecasting (horizon) Deviation and near-miss analysis Preparedness planning Business continuity planning Emergency preparedness Government lobbying
Recovery	Ability to return to normal operations state rapidly.	Crisis management Equipment reparability Resource mobilisation Communication strategy Mitigation processes
Dispersion	Broad distribution of assets.	Asset and key resources decentralisation Distributed decision making Dispersion of markets Location-specific empowerment
Collaboration	Ability to work effectively with other entities for mutual benefit.	Disruption sharing with partners Supplier relation management Client and customer relations management Collaborative forecasting **Communication and information pooling***
Organisation	Human resources structures, policies, skills and culture.	Empowerment Creative problem solving Accountability including reporting (Cross-) training and workforce flexibility Culture of caring **Functional information coordination***

Market position	Status of organisation or its product/services in specific markets.	Product positioning Market share Brand equity Customer service management Sustainable position Customer loyalty/retention
Security	Defence against deliberate intrusion or attack.	Access restrictions Employee involvement Collaboration with governments **Staff and customer security*** Cyber security Layered defences **and protective measurements*** **Fraud detection***
Financial strength	Capacity to absorb fluctuations in cash flow.	Financial reserves and liquidity Price margin Insurance Portfolio diversification

* Sub-factors in bold are changes compared to the initial lists.

8. Balanced resilience and managerial implications

This section will continue to develop an understanding of the resilience management process. It will discuss the fourth research objective: To ensure that public transport organisations are able to make linkages between vulnerabilities and capabilities. For this to occur, it is essential that public transport organisations are able to measure and rank vulnerability and capability factors to determine their importance. In addition, critical linkages between these factors need to be recognised so that public transport management can utilise this information to manage purposeful change towards the desired state of resilience – to be referred to as the *to-be status*. The capacity of the public transport organisation to measure, determine the importance of and identify critical linkages between vulnerabilities and capabilities will be referred to as *balanced resilience*. A two-step approach is developed to achieve this. First, a survey-based assessment tool is developed to measure and rank the vulnerabilities and capabilities. Second, the validity of the identification of critical capability linkages is discussed. In this way the ability to accurately measure the construct of resilience will be attained.

The findings of the expert meeting are summarised here:
1) Public transport organisations have unique features in addition to their common activities. Comparisons between public transport operators must be viewed in the context of different legal structures (in Europe), as well as from the perspective of the different modes of transport (bus or rail (tram, metro) or water). The identification and measurement, ranking and linking of vulnerabilities and capabilities must be placed in the perspective of the *function* of the public transport organisation.
2) The resilience approach needs to focus on the strategic level. The approach is based at the level of the organisation. Organisations have different approaches to the distribution of responsibilities. The *framework is applicable* within a more centralised as well as with a decentralised distribution of responsibilities. The results of the identification of vulnerabilities and capabilities may differ, based on the organisational approach (leading to insights related to responsibilities in the organisation on vulnerabilities and capabilities), which has implications for the measurement, ranking and linkages between vulnerabilities and capabilities.
3) The concept of resilience is applicable in public transport organisations and they have the ability to derive a balanced resilience position.
   - Public transport organisations are, like any other organisation, learning entities. The framework provides a structure for them. The concept of *contextual resilience* is considered important, and public transport organisations are able to develop this.
   - The framework is considered as comprehensible and comprehensive, and relevant to public transport organisations. Public transport organisations are able to identify, assess and respond to disturbances in order to become resilient. The concept of *cognitive resilience* is accepted, and public transport organisations are able to use the framework.
   - Taking the context of the previous results into account, public transport organisations are able to use proactive diagnostics in the identification of potential vulnerability and capability factors, which enable them to structure and to react systematically when something unexpected occurs. The concept of *behavioural resilience* is accepted, and public transport organisations are able to analyse the vulnerabilities and capabilities presented.
   Within in this context:

- Public transport organisations are aware of the limitations of their knowledge in a rapidly changing environment;
- Public transport organisations are able to measure, rank and create linkages at factor level and to judge their relevance in relation to the performance indicators related to the mission statements.

- Vulnerabilities and capabilities need to be linked. Given the short time gaps between analysing both, the linking process may start with either one. Organisations are most likely to start with analysing disruptions. The short-cycle approach is relevant when using the framework. Public transport organisations are able to work towards a *balanced resilience approach*.

4) Introducing resilience is possible, but its urgency is not evident.

- It is relevant to understand the culture of the organisation. How open are organisations to disruptions and in what ways are they willing to discuss this internally and externally? There is a need for more openness to understand vulnerabilities.

- Contracts with the transport authority will determine the priorities. There is the effect of penalties if contracts are not fulfilled. Performance indicators need to include what is asked in contracts or what is critical to customers. Resilience can become a competitive element if triggered by authorities or customers.

- Public transport organisations are not network-oriented for improvement.

5) Public transport organisations need to introduce the management process of resilience systematically as an innovative action from a strategic point of view. From the discussion, the following challenges are identified (not in order of importance):

- Complexity increases: organisations are challenged more frequently externally;

- Visibility is limited: priority is given to day-to-day business interruptions rather than to vulnerabilities;

- Accountability is not clear: who is the problem owner and what are the responsibilities of the respective stakeholders?

- Willingness to engage is limited: what are the benefits internally and externally?

- Justification: absence of metrics in cost and revenue indicators;

- Relevance in relation to other strategic issues: relevant but not urgent.

From this, the following suggestions are offered for implementation of a systematic organisational approach:

- Because both risk and resilience management will become competitive elements in the future, knowledge of the resilience management process

of public transport organisations needs to be improved.

- Introduction of the resilience approach needs to be enforced from the outside. Public transport organisations will not take the lead. External forces need to stimulate initiation of the resilience management process.

The expert meeting confirmed the relevance of the concept of a resilience approach and the use of the framework, and affirmed the ability of public transport organisations to create a balanced resilience

9. CONCLUSION

Organisational resilience can be defined as *the capacity to survive, adapt and grow in the face of turbulent change*. Three major dimensions of resilience are relevant, namely the capacity to prevent a bad occurrence; the capacity to prevent a bad occurrence from worsening; and the capacity to recover from a bad occurrence.

Public transport managers should be encouraged to determine their organisation's current state of resilience and analyse the different effects on, for example, productivity and the difference in time to recover, when incorporating a resilience approach and when not. The ability to structure linkages presented in this research provides clear directions for the management of public transport organisations to take the necessary actions to improve critical capabilities, maintain high-priority strengths and reduce unnecessary expenses. These actions, closely monitored and managed over time, will lead an organisation towards a state of more balanced resilience. Public transport organisations need to balance revenue streams with preparation and recovery costs, short-term customer service and long-term value in terms of return on assets. Thus assessment and periodic reassessment form the basis of managing the dynamic portfolio of capabilities that are best matched to the pattern of inherent vulnerabilities to ensure resilience in public transport organisations in a world of turbulent change.

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