RTI Capabilities of Air Cargo Transport Chains by Evaluating Processing Interfaces and Actor's Responsibilities

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Abstract: *The issues outlined as follow are based on results of the ACCIA project which have been manifold, due to its being a subject formatting study. By summarising these results, first a documentation of the field of airfreight based on introductory literature and an exploration of official statistical sources on airfreight traffic are given. Subsequently, a deeper analysis of the airports investigated will be shown, whereby essential information was gained on exploratory field visits and by expert discussions on-site. All these insights into air cargo handling and transportation are essential for identifying and characterising the interfaces along the several airfreight transport chains. Based on this information, methodological approaches for analysing the processes along the air cargo transport chains are outlined. Finally, these procedures lead from the interfaces detected to determining application fields on to potential targets for identifying Research, Technology and Innovation RTI-potential. Ultimately, comments are made on these perspectives as to their significance for the future. The interface navigator developed as part of the study can serve as a basis for the step by step implementation of a physical internet along the complex air cargo transport chain.*

Keywords: *air cargo transport chain, system of the interfaces, Air Cargo Centre, RTI-potential, personalisation, formalisation, digitisation, automation, decarbonisation, air cargo interface navigator*

1 Introduction

The study “ACCIA – Air Cargo Research and Capabilities in Austria” (Dörr et al., 2016) was carried out as a research and development service for the Austrian Ministry for Transport, Innovation and Technology (BMVIT) within the frame program “Take Off” and was completed in 2016. The report was worked out by the leading Civil Engineer Office arp-planning.consulting.research, DHL Global Forwarding Austria and the Vienna International Airport.

The background for the study was the assumption that with reference to the year 2010 air cargo traffic will be doubled until 2030 (Take Off, 2014). Mass goods with a low weight per piece and high-quality goods determine the volume of freight in aviation. However, the transport of the goods by aircraft is only a part of the transport chain and must be coordinated with pre-carriage and on-carriage according to the modes of surface traffic.

The following questions were discussed in the research and development phase:

- What are the deficits, gaps, problems and challenges in the field of air cargo processes in Austria?
- Which specific interfaces in the air cargo transport chain are affected?
- How can the deficits, gaps, problems and challenges identified be met with R&D?
- What potentials could be created?

- Which actors should be involved in order to raise these potentials?
- What visionary concepts already exist among the interface logistics/freight traffic/aviation?
- Which visionary concepts should be followed up by R&D?
- What basic conditions (technical, organisational, legal) should be taken into consideration?

2 Air Cargo Transport Chains – A Complex Challenge

Air cargo transport chains are characterised by the various actors involved, by a fiercely competitive market and by a wide range of logistical quality requirements, which are determined by the customers. Nowadays, almost all goods can be flown as airfreight, provided that they do not exceed the mass transport capacity of the aircraft. Shipping and receiving airfreight customers are broadly diversified by sector and region. Nevertheless, major shippers with a high global export shipping volume, the specialists in the forwarding businesses and the air cargo freight carriers symbiotically converge by means of contract logistics. Thus, the cargo belly load in the lower deck of passenger aircrafts meets their economic expediency just as well as transport via cargo aircrafts does. Furthermore, passenger aviation offers scheduled flights departing from economical hot spot regions for spontaneous consignment missions also to remote located destinations (see Figure 1).

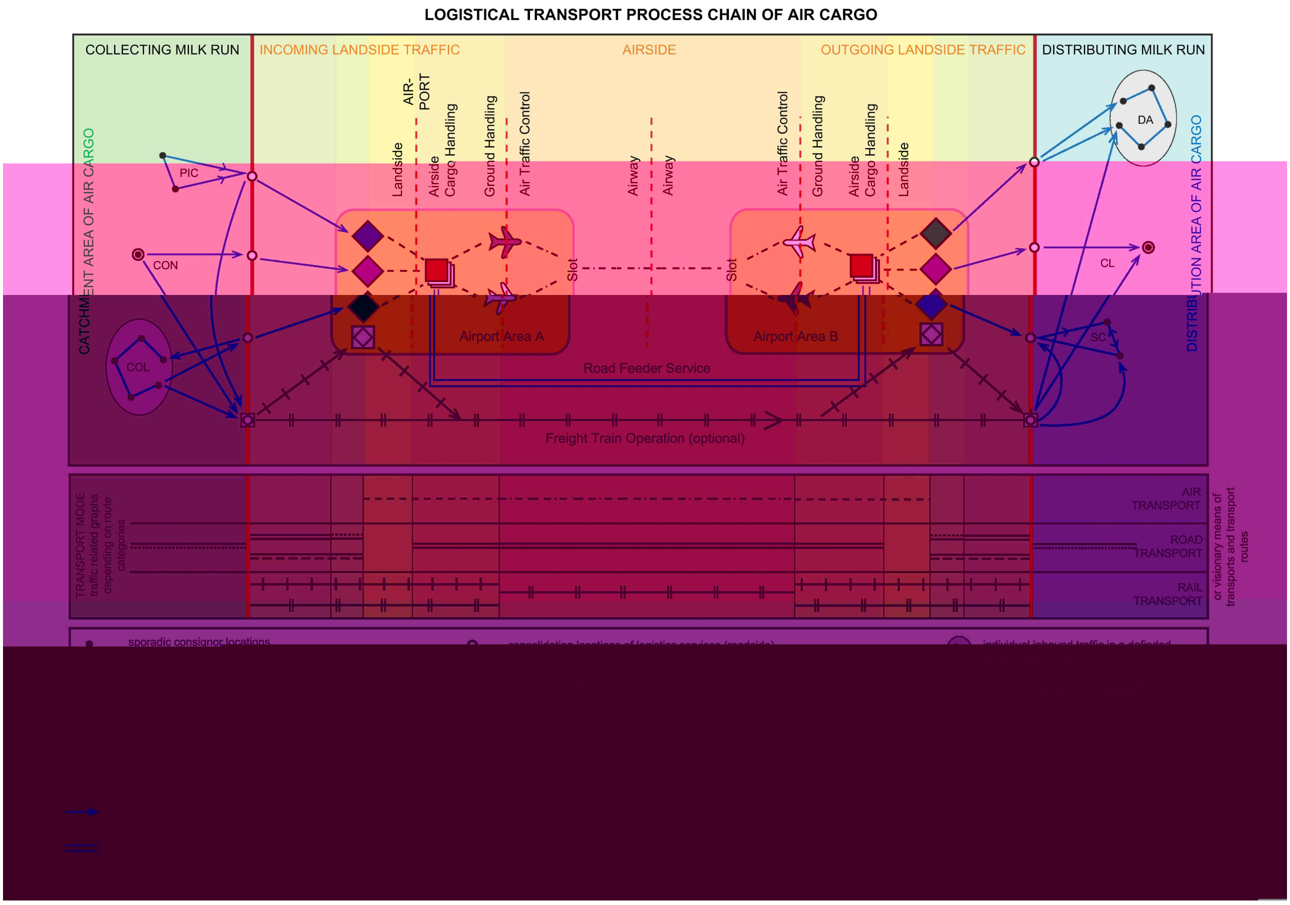


Figure 1: The air cargo transport logistical process chain, sourced from Dörr et al., (2016)

Global hubs, such as Frankfurt/Main (FRA) or Vienna (VIE), achieve their freight volume mainly in both air cargo transport modes — excluding Road Feeder Service (RFS) only as belly load in the lower deck of passenger aircrafts or as transport via cargo aircrafts. In addition, airports with regional or touristic passenger volume, such as Linz (LNZ), Leipzig/Halle (LEJ) or Liège (LGG), have developed as niche players in certain segments of the air cargo business.

3 Airports seen as Locations with Potential

In terms of each airport as a location for itself, the potential for air cargo traffic can be described by three dimensions:
1. the hinterland potential as demanded by the air cargo affine economy,
2. the destination potential based on the quality and quantity of flight connections to and from a hub airport,
3. the location potential (capacity and quality of service) of an airport as a hub and consolidation centre with respect to space and traffic.

The significance of commercial airports cannot be determined solely by considering the dimension and the success factors. In view of globalisation and the integration of the European internal market, these factors are to be understood as a gateway to the world, providing the necessary infrastructure for the economy of the hinterland.

The airports with their handling facilities for airfreight alone do not yet serve as a growth engine for an economic region, but as an important location factor they could indeed greatly facilitate trade relations and industrial development. In this respect, the Austrian commercial airports are analysed qualitatively by the aspects of the historical development and the current status, the importance of the airport by analysing aviation statistics and transport services, the operating infrastructure, the development as an economic location and synergies with the surroundings and the hinterland and the economic catchment area for air cargo. Referring to cargo handling, it is subsequently attempted to assess the potential of the Austrian airports.

To summarize up, air cargo is not just an Austrian phenomenon, but something which is happening globally. Analysing Austrian airports might even show that the problems and challenges are not limited to being national issues. Regional airports are often located near hubs, showing that this might indeed be a European problem, if not an international one.

4 Air Cargo Transport Modes in the Transport System

In the case of air cargo transportation, the overland transport system, almost exclusively road transport, is used to supplement air cargo transport chains in two ways. On the one hand, it provides a pre-carriage and on-carriage transport service to the airports; on the other hand, it functions as a road feeder service between two airports instead of inner continental transport by aircraft. Aside from major customers, the tracks of air freight shipments are lost as soon as they have reached the consolidation logistics warehouses in the vicinity of the airports. This is because these goods’ flows disappear in the general flows of goods transported. The traffic modelling of the inflow and outflow of lorry-borne air cargo transports from domestic airports has resulted only in a marginal share of the entire heavy duty traffic in the road network of long-distance routes. As a whole, significant potential savings of freight runs are to be found elsewhere in the fields of freight transport and vehicle traffic onto road network.

The model of lorry-borne traffic generation of an Air Cargo Center shows the complex ingoing and outgoing movements of various utility vehicles serving air cargo transportation overland and transhipments to main runs by aircraft (see Figure 2). The Air Cargo Center bundles/debundles not only physical goods as well as it works as a focal point for different shaped supply chain processes for various customer´s needs and commodity requirements.

Although lorry-borne shipment per continental land transport of airfreight is notable, it is necessary to mention, that each road-carried ton of payload produces less emissions than each flown-carried ton of payload. However, if a network of railway connected airports could be built up (e.g. Euro Carex), some of the lorry-borne airfreight transports could be shifted to the more climate-friendly railway. In any case, the multimodality of airports is a marginal issue here, so that convincing operations models, which would justify infrastructure investments in the railway connection of the air cargo centres, are sorely lacking.

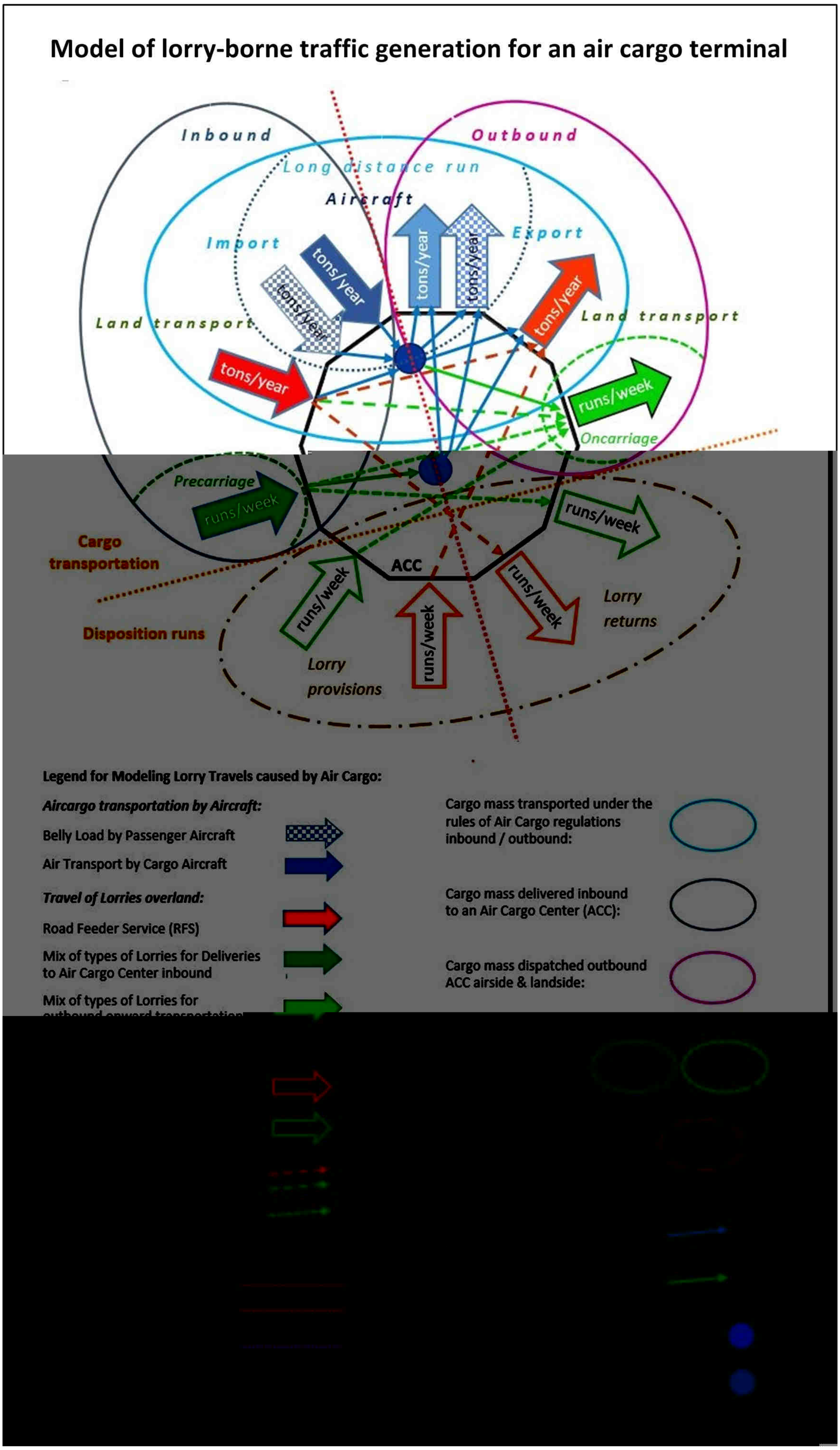


Figure 2: Model of lorry-borne traffic generation for an air cargo terminal, sourced from Dörr et al. (2016)

5 Actors and Functions of an Actor

The actors involved along the air cargo transport chain have different ranges of services; this means that the attribution of a function at an interface is not always unambiguous. This is due to the fact that actors do not carry out only those functions as might be assumed in detailing the distribution of roles between customers, forwarders, cargo handling, ground handing, airlines and so on. For instance, Unit Load Devices (ULD) do not have to be set up by a cargo handling agent in the air cargo terminal of an airport, although this as a rule does occur. Another example is airlines offering air transportation and other additional preceding or subsequent services in addition to their core business. Due to liberalisation in aviation ground handling, several providers originating in different business areas are also able to offer their services at an airport. Consequently, the authors of this study have introduced the term **functions of an actor** to refer to these differences. Hence, a function can be practiced by one or more actors (see Figure 3).

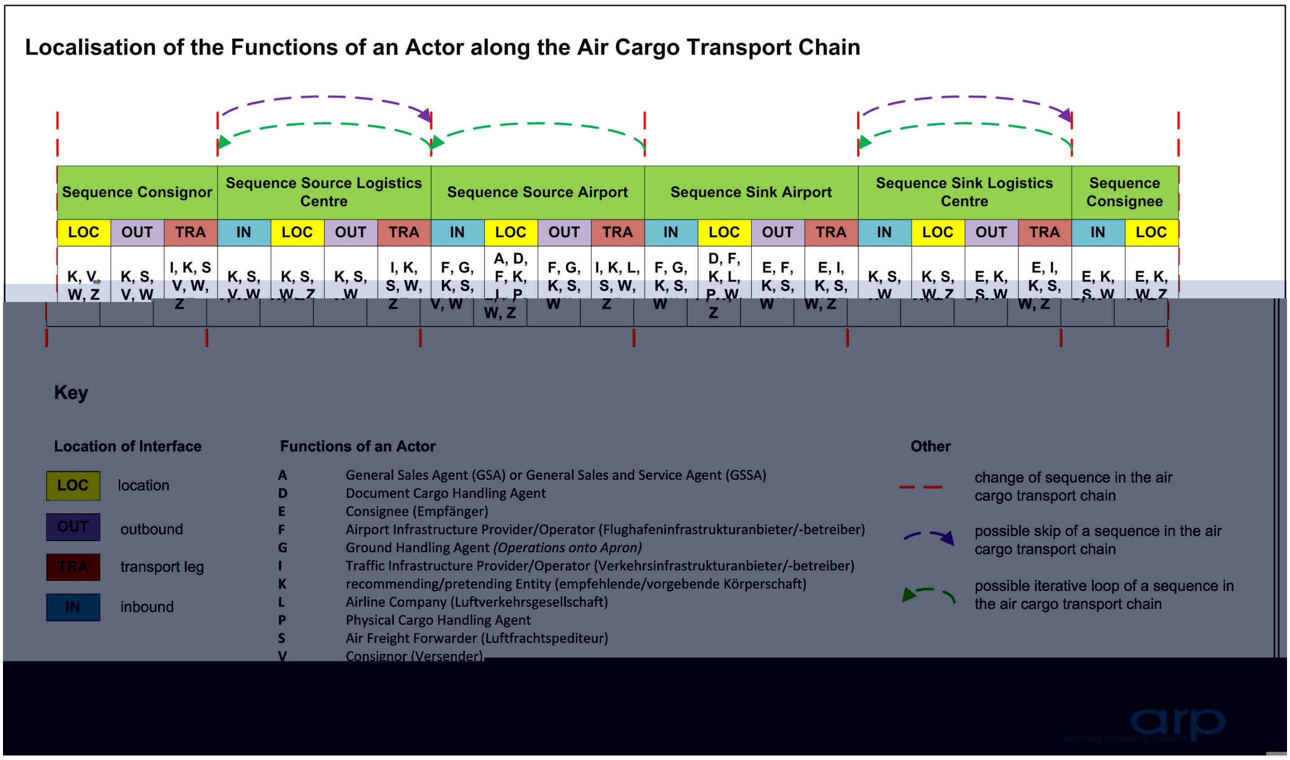


Figure 3: Localisation of the functions of an actor along the air cargo transport chain, sourced from Dörr et al. (2016)

6 Interfaces as a Guideline in the Process Chain

The air cargo transport chain can be regarded from three different points of views. Firstly, there is the *transport geographical view*, which analyses the sources and destinations of transports in the transport infrastructure network. Secondly, there is the *view of responsibility*, which describes the sphere of responsibility of the actors involved. Last but not least, there is the *view of single sequences*, where the locatable process areas (warehouse location, ramp, transport legs, etc.) of traffic logistical functions and processes, such as a loading activity or cargo handling, are explored. These process areas describe the localisation of interfaces as well as the sphere of responsibility of the actors interacting at an interface. In every case the air cargo consignment represents the object to be treated. The treatment which takes places at an interface not only affects the physical process of handing over of the consignments, it also affects the transfer of responsibility.

In order to achieve a graphically attractive system for the interface scenery of different air cargo transport chains, the interfaces were initially classified by their technical-related and functional-related characteristics. These characteristics were grouped into *informational* (data flows of organisational relevance), *infrastructural* (performance features of the available transport infrastructure) and *processual* (necessary operating processes based on the consignment structure and the security regulations) interfaces (see Figure 4). Additionally, the interfaces were classified according to their *degree of indispensability*. This was done because some interfaces had to be complied with at a certain location. Others may occur multiple times or in local variations. Last but not least, there are also interfaces, which might be switched on optionally, e.g. due to special consignment requirements.

In the next step, the **chronological-spatial arrangement** of the interfaces was determined. In order to do so, the air cargo transport chain was subdivided into *action-related sequences*. These were then subdivided again into the process *areas "inbound", "location", "outbound"* and *"transport"*. Individual sequences can be left out or can be repeated, depending on the respective airfreight transport chain. Subsequently, the interfaces were arranged according to their **transport modality**, whether they relate on the transport run to the aircraft (✈), on the transport run via RFS (🚚 RFS), on the transport run in the pre-carriage or on-carriage to the lorry (🚚), on the consignment itself (🎁) or to a possible ULD service in pre-carriage or on-carriage (✈). The authors of the study called this **interface navigator**, because it can be used as an orientation tool for evaluating, optimizing and estimating the development potentials for the majority of air cargo transport chains (see Figure 5).

informational	**COM - *(IT) Communication* -** *(IT) communication for carrying out the airfreight transport with regard to queries, responsibilities, data provision and so on.* In case of queries, responsibilities etc., (IT) communication is sometimes required for the reciprocal (electronic) transmission of information. Experiences, findings and knowledge (possibly by request) as well as important data for the fulfilment of an air cargo transport chain are thus to be transmitted (hurrying ahead) between at least two actors along an air cargo transport chain. IT communication can also be automated; by setting tracking point an automated message it can be sent to an interested actor.
infrastructural	**LLP - *Loading Area/Loading Ramp/Parking Position* -** *Suitable lorry loading areas/loading ramps or aircraft parking positions with adequate area and amount.* Loading areas and loading ramps are areas or points which are used to load or unload lorries. Parking positions are ground parking spaces for aircrafts, on which the loading is carried out and the aircraft is prepared for the next flight. It is important to provide mutable loading zones, loading ramps or parking positions in order not to delay the loading operations. Situational, spontaneous charging zones (e.g., second lane) may arise due to a high traffic volume or a lack of infrastructure.
processual	**AOG - *Aircraft Operations/Ground Handling* -** *Measures/activities that are directly associated with the landing, take-off and turnaround of an aircraft, as well as indirect activities such as the transport of shipments from the air cargo terminal to the aircraft.* Aircraft operations/Ground Handling include activities that must be executed. These activities can be directly associated with the landing, turnaround or the take off of an aircraft. These include e.g. the clearance of take-off, the landing permission, the push-back, the refuelling, the clear assignment of parking positions or technical checks, as well as the transport of consignments from the transfer station or staging area of an air cargo terminal to the aircraft and vice versa.

Figure 4: Examples for informational, infrastructural and processual interfaces in the air cargo transport chain, sourced from Dörr et al. (2016)

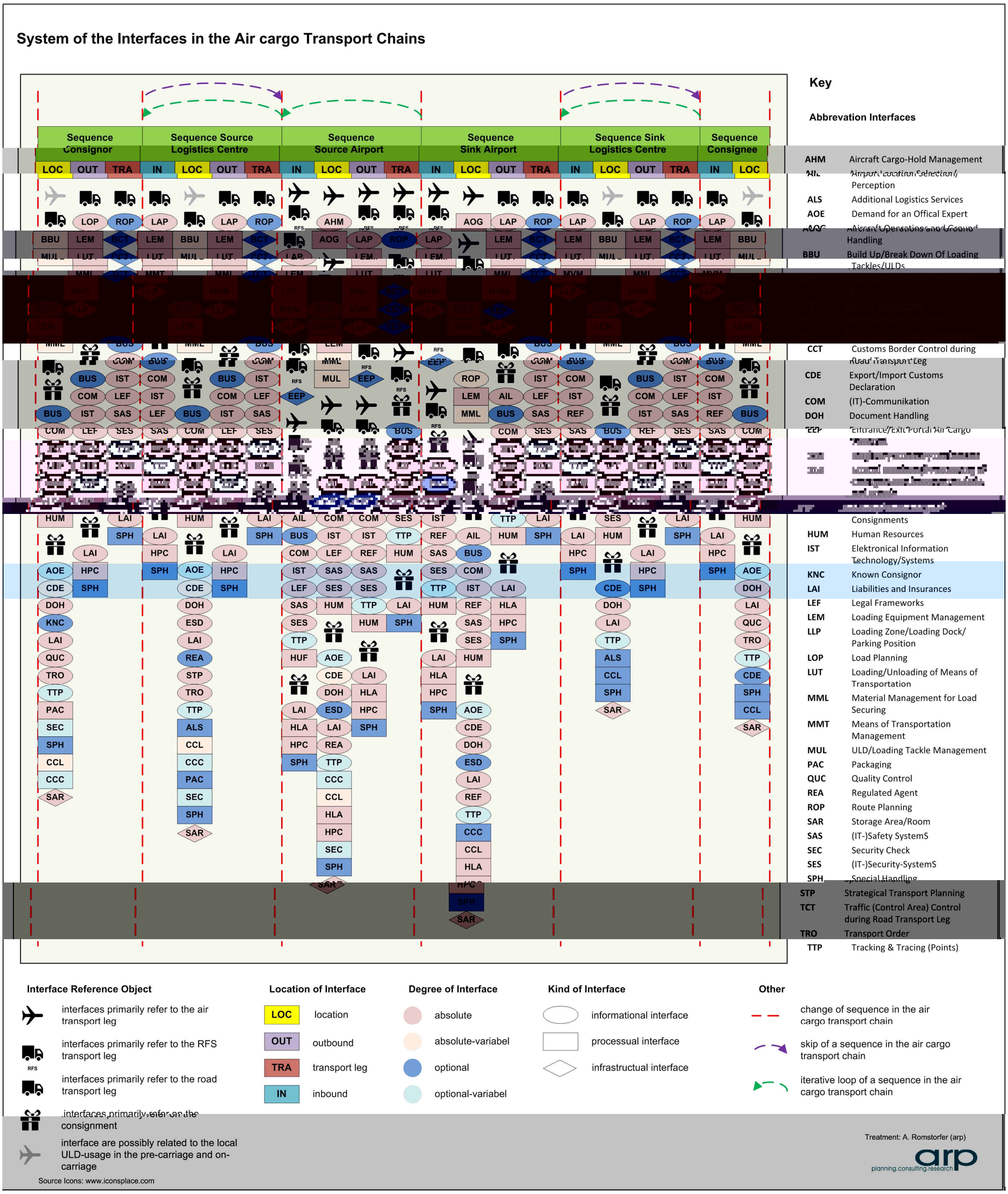


Figure 5: System of interfaces in the air cargo transport chains, sourced from Dörr et al. (2016)

The complex framework conditions are a daily challenge for all service providers active are in the air cargo transport chain. Consequently, their efforts to standardise and harmonise the processes by providing flexible handling service in keeping with the wishes of the customers and under consideration of safety and security regulations are quite remarkable in a qualitative tensional relationship. Nonetheless, these circumstances make economical rationalisations and technological optimisation difficult to implement, if the market positions of the involved actors are not to be jeopardised.

7 RTI Potentials in intervention points and fields of application

On the basis of a strength and weakness conclusion in the range of air cargo, potential on-site intervention points and fields of applications are identified for possible research and development activities. Therefore, all 43 of the interfaces identified are examined on their suitability for prospective RTI-capabilities by evaluating the localised intervention points in the five fields of applications defined. These fields are Personalisation, Formalisation, Digitisation, Automation and Decarbonisation.

Firstly, this individual valuation results in statements on measures that influence particular locations such as the landside or the airside of an airport or the apron in front of an air cargo centre. However, a list of intervention points for improvements, upgrades or changeovers may never be complete. This is not least due to the fact that operational details in the processes of the respective actors can be very diverse. They may also not always be observed and described on grounds of confidentiality and safety reasons. The summary results for the process areas along the air cargo transport chains, where interventions could be placed, thus seem more revealing. In addition, a ranking were performed to identify primarily RTI-potential. Therefore, the interfaces identified were subjected to a strengths-weaknesses analysis. These strengths and weaknesses were extracted e.g. during expert discussions and/or where they were obvious on on-site inspections. As a next step, the strengths and weaknesses identified were then used to identify intervention points which can influence the process design in the air cargo transport chain. For a closer assessment they were evaluated in the five fields of application defined:

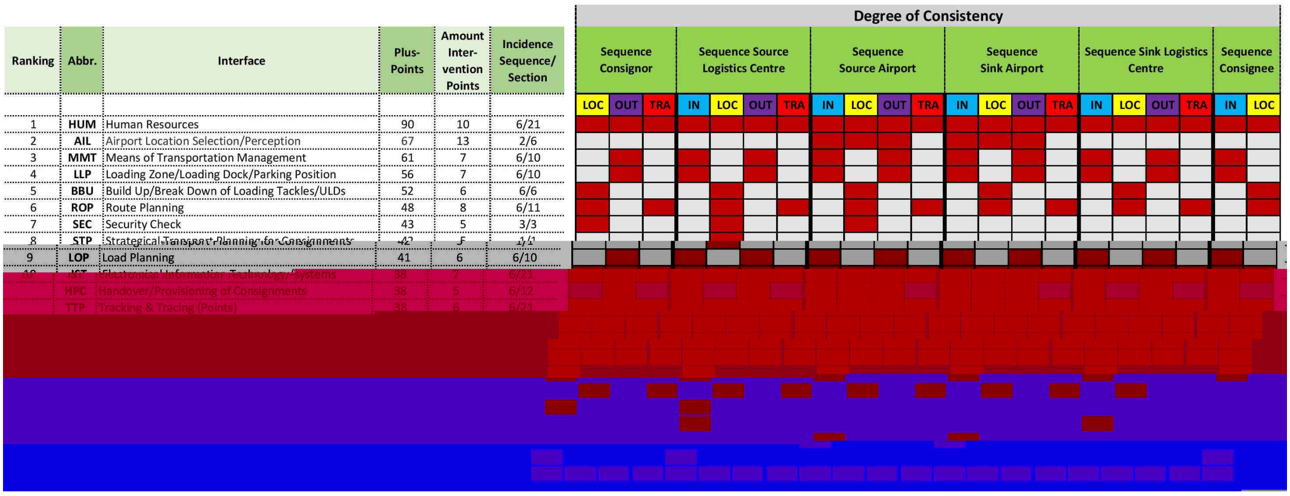
- **Personalisation:** all services provided by human resources in the airfreight transport chain,
- **Formalisation:** all activities that are used to define tasks and structures or configure processes,
- **Digitisation:** networking of objects along the air cargo transport chain by using information and communication technology,
- **Automation:** conversion to automated processes for the support, facilitation and precision of processes,
- **Decarbonisation:** all measures and conversions to encourage post-fossility.

While the intervention points represent the possible or even urgent tasks, e.g. with regard to the climate change or possible integration of the physical internet, the fields of application refer to the solutions and fundamentally show where the competencies in the professional world could be located. However, the evaluation does not provide a general assessment. It rather contains references to the potentials that can be activated.

The qualitative evaluation of the respective intervention points was carried out by using three differently weighted plus symbols (+ for estimated RTI-potential, ++ for significant RTI-potential, +++ for very high RTI-potential). Figure 6 gives an example how such a finding could be figured out and Figure 7 presents a high-score summary of this evaluation procedure. The fields marked red represent the interfaces with the highest RTI potential while the fields marked yellow represent the interfaces where a high potential can been estimated. The Figure also shows the localisation of the interfaces in the sequences and sections along the air cargo transport chains. The term **Degree of Consistency** was used for this. However, whether all of the intervention points for an interface are in fact of significance in each localisation sequence or sector, will have to be subject to additional closer consideration.

Processual interface	Sequences concerned / Process area localisation	Status Quo	R&D-Intervention Points within the Process Chain (selected actions)	R&D-Potentials in application fields				
				Per	For	Dig	Aut	Dek
BBU – Built Up / Break Down of Unit Load Devices (ULD)	1, 2, 3, 4, 5, 6 / STA	-	Action analyses stuffing containers according to flight plans	++	++	++	++	+
			Action analyses built up ULDs according to aircraft load plan	++	++	++	++	+
			Special application of robotics for ULD BuildUp/BreakDown		+++	+++	+++	
			Treatment of goods in export procedures in dependence of climate conditions in their destination´s evironment	++	++	++	++	
			Treatment of importing goods in dependence of their origin	++	++	++	++	
			Technical development of moveable robots for ULD-treatment		+++	+++	+++	

Figure 6: Potential finding matrix: Example for one of 43 identified interfaces, sourced from Dörr et al. (2016)



Ranking	Abbr.	Interface	Plus-Points	Amount Inter-vention Points	Incidence Sequence/ Section
1	HUM	Human Resources	90	10	6/21
2	AIL	Airport Location Selection/Perception	67	13	2/6
3	MMT	Means of Transportation Management	61	7	6/10
4	LLP	Loading Zone/Loading Dock/Parking Position	56	7	6/10
5	BBU	Build Up/Break Down of Loading Tackles/ULDs	52	6	6/6
6	ROP	Route Planning	48	8	6/11
7	SEC	Security Check	43	5	3/3
8	STP	Strategical Transport Planning for Consignments	42	5	1/1
9	LOP	Load Planning	41	6	6/10
10	IST	Electronical Information Technology/-Systems	38	7	6/21
	HPC	Handover/Provisioning of Consignments	38	5	6/12
	TTP	Tracking & Tracing (Points)	38	6	6/21

Figure 7: Ranking of the interfaces with high RTI-potential and their localisation in the sequences and sections along the air cargo transport chains, sourced from Dörr et al. (2016)

The aspects of *Personalisation* are a common thread in all fields of application. A dominance of the field of application *Formalisation* was confirmed by the numerous expert discussions. The greatest potential here lies in the continuity and transparency of a process chain, but this requires a screening of all overlapping actors along the process chains, which however would interfere into the internal company structures. In view of the large number of actors involved, such initiatives must be established on a manageable platform, i.e. at least at the levels of sequences. This presupposes the willingness of communication and cooperation of all actors involved in an air traffic hub.

Some weaknesses have been identified in the field of application *Digitisation*, which is dependent on the field of application Formalisation, whereas a great deal of expectations have been attached to the field of application *Automation*. If the automation of processes lies in the proprietary decision-making area of the actors and the public areas or the traffic areas are not used by automated units or means of transportation, such an upgrade or changeover will be practicable immediately. The use of robotics and mechatronics is certainly dependent on the individual location and would be previously realised in varying degrees. The general penetration of the process areas along the air cargo transport chains with automation technology should be illuminated on the basis of quality objectives, because ambivalences, for instance in relation to the use of human resources, will occur.

It has to be assumed, that in the field of *Decarbonisation* it is the air transport itself that mainly produces most of the air pollution and greenhouse gases. All of the other process-related emissions appear less significant, although on-site land traffic and ground handling is able to be set up towards fewer emissions at any time.

In the global air cargo business it is easier to address the actors in the export business than in the import business. On the export side, concrete conceptions with respect to climate protection, environmental relief, conversion in the management of resources and cooperation between the actors have already been able to be realised from the beginning. On the import side, once commodities start their way overseas, the international harmonisation of the processes and the continuity of the timely information flows become more important. At best optimisations here can be achieved along the way from the arrival airport to the supply destinations. In any case, the activation of potentials lies not only in technological measures, but also in the rational mastery of the competitive market pressure and the willingness to use existing technologies in a manner which is oriented towards civilising goals for instance with better working conditions or climate protection. From a present-day point of view, the potentials mainly target the elimination of identified deficits by implementing state-of-the-art technologies.

8 Long-term Context and Visionary Perspectives

Looking even further into future, the assumptions of potentials are by nature speculative. These assumptions include knowledge of the development of new aircraft types and aerodynamic designs. In the ideal utopic case the entire transport chains of certain air cargo consignments could be shifted to airborne transportation. This means that the pre-carriage and on-carriage haulage could also be generally served by cargo-drones or cargo-airships landing almost anywhere. The next generation of aircrafts will not only be much more energy-efficient and produce lower emissions, there might also be less space needed particularly concerning the length of runways for starts and landings. This could mean a chance for decentralised airports in remote regions. Such perspectives would require a planned and regulated rearrangement of near-ground airspace particularly over densely inhabited regions. In land transportation the (partly) automated movement of vehicles in the transportation networks will undoubtedly be established. Furthermore, multimodal transport processes could be carried forward to all other transport modes depending on the interchangeability of air-typical traffic demand.

9 The Meaning of Physical Internet

The term Physical Internet was used for the first time in 2006 on the title page of the British economic journal Economist. However, the content of the related article refers conventional logistics processes. Inspired by the idea of Physical Internet, the Canadian scientist, Benoit Montreuil, decided to develop a concept that actually uses the protocols of sending data packets on the digital Internet to create more efficient and sustainable logistics (Ballot et al., 2014). The Physical Internet is defined as following: Physical Internet is an open, global logistics system based on physical, digital and operational interconnectivity ensured by modularisation, interfaces and protocols (Montreuil, 2012).

In a functional Physical Internet, all warehouse facilities with their current capacities and all means of transportation with a suitable route are available (Zentralverband, 2013). The centrally regulated routing system is coordinated in such a way, that the means of transportation and their drivers meet at hubs. There haulage and hauls can be reconsolidated to avoid transports with empty or partially filled charge carriers and shortens transport times. One particular feature of the Physical Internet are the uniform charge carriers (in the proper sense of modular container), which can be combined to any size (Petersen, 2013).

The objective of the Physical Internet is to achieve a higher utilisation of the transport routes. This is meant to provide significant economical (shorter transport times, less personnel costs) and ecological (traffic reduction, less CO_2-emissions) advantages. A balanced utilisation of storage facilities and distribution centres is also striven for and drivers could be deployed on short hauls as possible (Logistikknowhow, 2015).

It is alleged that the Physical Internet will be more effective the more actors and companies are using this organisational structure (Industriemagazin, 2015). This reorganisation of freight transportation can be made possible by the continuous improvement of the supporting information technology. Consequently, the Physical Internet is a concept which should include freight transportation and information exchange in an equivalent way. Intralogistics is also an important prerequisite for an effective system. Coming straight to the point, the Physical Internet is a highly interdisciplinary topic (see study AIDA-F (Dörr et al., 2015) for interdisciplinary topics), which includes such sub-topics as synchromodality, supply chain resilience, efficient value chains, information transparency, information security and the Internet of Things. The building up of the structure Physical Internet offers new possibilities in logistics, yet it would also create new challenges, which will probably necessitate a fundamental rethinking on the part of all of the actors in logistics networks.

According to the project ATROPINE the "physical internet" consists of 13 characteristics (Schauer et al., 2016):

- standardised, ecological, modular and intelligent containers,
- universal interconnectivity,
- container handling and container storage with PI-containers,
- interconnected containers with integrated smart tags,
- from point-to-point and hub-to-spoke transportation to intermodal traffic,
- a unified multi-layered conceptual model,
- activation and use of an Open Global Supply Web,
- design of products for minimum space requirements,
- transport minimisation and warehouse minimisation through digitisation and local production,
- open performance monitoring and performance certification,
- reliability and failure safety of networks,
- creation of innovative business models,
- creation of an open infrastructure.

The idea behind the Physical Internet is that the entire transport chain, not just certain segments, is to be optimised. The transport chain can be simulated by working on the interface navigator allowing PI-researchers to be able to recognise where PI-potential might occur. This may even span all segments.

10 Conclusion

A central research task has been to present the complexities of air cargo transport chains as completely, comprehensibly and representatively as possible. As defined in the previous chapter, the existing interfaces along a transport chain are an important basis for implementing Physical Internet in logistics. These interfaces have to be served by the actors involved. In this way, almost all existing interfaces and actors involved were dealt with. By means of local inspections and professional discussions the interfaces were able to be identified and positioned along the air cargo transport chain. Furthermore, the functions of an actor were able to be assigned to each interface. As a result, technological and organisational fields of applications were able to be defined. These in turn were provided with (traffic-)logistical intervention points at each interface in which general improvement and development potentials as well as research gaps were set. The interface navigator was developed as a guideline to serve as a basis for implementing Physical Internet along the complex air cargo transport chain step-by-step.

The study ACCIA also found out that there are a great deal of physical elements along the air cargo transport chain, but that these have not yet been completely interconnected. Nevertheless, the air cargo transport chain could become prototypical for a gradual realisation of Physical Internet, not least because of the strict safety and security regulations in aviation business. On the one hand, there would be challenges for Physical Internet to cope with data security, data confidentiality and reliable business relations where information should not or could not be transmitted in an unobjectionable manner. On the other hand, in cases of emergency the transport of commodities which are consignments might prove to be a big chance, when the consistency of information transfer is essential to handle them as preferred and sensitive cargo.

Air cargo transport chains are by no means perfect but they work conveniently for shippers and regional economies. In some way they fulfil basic services and basic democratic functions, particularly for rather remote regions all over the world.

Due to a strict degree of standardisation and open monitoring fully developed Physical Internet might indeed neglect some customers' requirements and expectations concerning service quality and reliance. In the long run this will probably lead to the restoration of a centrally planned economy. Who will be the manager and the controller?

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