Innovative Baggage Delivery for Sustainable Air Transport

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Abstract—**The passenger travel processes in Air Transport (AT) have not changed for the past 40 years. Here we contribute to the IATA visions of Simplifying the Business (StB) and improving the passenger experience by proposing to dissociate passenger travel and baggage delivery. This innovative aspect has profound positive consequences on the AT logistics and economies. Even though it requires a significant change in the current AT regulations, the proposed improvement is likely to be phased-in and eventually adopted by the airlines as well as the aircraft manufacturers. Our analysis shows that dissociating passenger and baggage flows can be vital for maintaining sustainability of AT. Moreover, the enabling technologies supporting this change either already exist, or are being developed.**

Index Terms—**Air Transport, Baggage delivery, Passenger experience, Simplifying the Business, Sustainability.**

1. AIR TRANSPORT AND IATA VISIONS

The infrastructure, processes and systems in AT have not changed for over 40 years, so they are dated, inefficient and complex. Some of the main challenges are passenger queuing at various check and service points at the airport, mishandled bags, and unexpected service disruptions, for example, due to a bad weather or aircraft maintenance. These problems are causing excessive delays and costs, and they are exacerbated as the passenger numbers and the cargo volumes grow faster than the system capacity [1], [2]. For instance, the number of passengers worldwide has increased from 1.89 billions in 2003 to 3.3 in 2014 (i.e., a 75% increase).

The airlines and the airports have been well aware of these problems. The IATA (International Air Transport Association) established several programs to accommodate the growing demand for the AT services [3]. These programs are structured around three main objectives: 1. Airline products with new distribution capabilities and e-services, 2. Real-time interactions, and 3. Seamless and hassle-free services. The latter objective concerns the relevant themes such as Smart Security, Baggage Services, Security Access and Egress, Automated Border Control and Fast Travel. In simple terms, the overall aim is to simplify the processes and improve the passenger experience while enhancing the security, safety, and the utilization efficiency of space, staff and other assets. The passenger experience is improved by providing them with more autonomy which have focused so far on baggage self-tagging, baggage self-drop-off, and self-checking services.

2. AIR TRANSPORT OF PAX, BAGGAGE AND CARGO

The AT network realizes the delivery of passengers, their baggage and cargo. This delivery is a very complex process consisting of many integrated services and supporting subprocesses. The aircraft serving as the AT carriers have finite volumetric and weight load capacities which are usually optimized to maximize the delivery efficiency [4], [5], [6]. Such efficiency can be measured as a revenue for the operator (e.g., an airline, or an airport), and increasingly also in terms of the generated CO_2 emissions [7], [8]. For the long-term average seat occupancy of about 80%, the long-haul flights generate a modest $6 profit per passenger, however, a substantial profit of $2.40 per kilogram of cargo [1], [3]; it is clear that cargo delivery is critical for the airline financial viability [9].

A typical commercial airliner trades-off the payload with its operational range as shown in Fig. 1. The payload-range trade-off curve also depends on the particular aircraft configuration (e.g., whether using the winglets) and the engine parameters. The payload only represents passengers, their baggage and cargo; the dry operating weight (DOW) includes everything else except the fuel [7], [8]. The maximum take-off weight (MTOW) is limiting for longer flights whereas the maximum landing weight (MLW) is a concern for shorter flights. The maximum zero-fuel weight (MZFW) becomes limiting when the payload and fuel are optimized for a given range. In Fig. 1, R_1 is the maximum range with the maximum payload. The ranges between R_1 and R_2 require to trade-off the payload for fuel. The maximum range R_2 achievable with full fuel tanks can be exceeded if the payload is further reduced to make the aircraft more fuel efficient. The payload-range trade-off of the new aircraft designs corresponds to R_3 (see Section 4).

The average passenger weight (combined male and female) is 73-75kg and the child 34-36kg [10], [7]. The hand (carry-on) luggage and checked-in luggage allowances differ per airline and the travel class: an economy class passenger on a long-haul flight is usually allowed to carry up to 7kg single luggage on board, and to check-in one piece of luggage up to 23kg for free. The maximum seating capacity of an aircraft decreases with the number of travel classes offered. A long-haul airliner typically carries: 240-520 passengers (80% occupancy) with 7kg average hand luggage per passenger, average checked-in luggage of 23kg (80% of travelers) and 2×23kg (remaining 20% of passengers) which amount to:

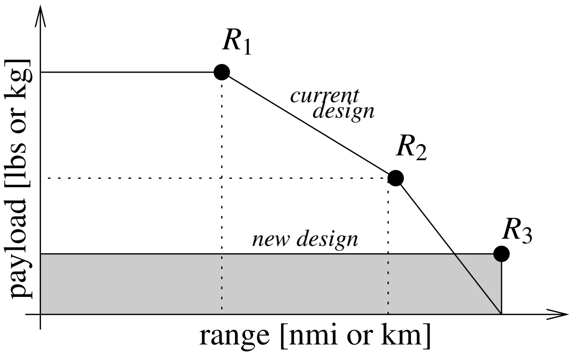

Figure 1. A typical payload-range characteristic of the current and future aircraft.

20-33	tons of passengers with hand luggage;
7-15	tons of checked-in luggage;
23-28	tons of cargo;
50-76	tons of the total payload.

The variants of the new Airbus A350 aircraft report the volumetric and structural cargo payloads of up to 52 tons [7], in addition to passengers and baggage. The purposely modified airliners known as the freighters can increase the maximum total payload of cargo to as much as 140 tons [7], [8].

The cargo is consolidated by the 3rd party forwarders (e.g., UPC, TNT, DHL) from the shippers and suppliers, usually into unit load devices (UDLs). The cargo delivery is optimized for efficient routing, loading and unloading and priority handling [5], [6]. The air cargo tariffs and premiums are determined to manage the demand against the available transportation capacity [3]. The average revenue per one kilogram of cargo delivery is calculated as [4]:

$$\mathrm{TRF}\ [\$/kg] = \frac{\sum_i \mathrm{CW}_i\ \times\ \mathrm{TRF}_i}{\sum_i \mathrm{CW}_i}$$

where $\mathrm{CW}_1 < \mathrm{CW}_2 < \ldots$ are cargo weights, and $\mathrm{TRF}_1 > \mathrm{TRF}_2 > \ldots$ are the corresponding tariffs. The tariffs can be determined through bids for the available carrier capacity.

A. Dissociating Passenger Travel and Baggage Delivery

Passenger travel as well as baggage handling and delivery is regulated by the IATA regulations. The IATA's General Conditions of Carriage [3] recommends that:

> "*. . . checked baggage will be carried on the same aircraft as the passenger unless Carrier decides that this is impractical, in which case Carrier will carry the checked baggage on Carrier's next flight on which space is available.*"

Moreover, most airlines operate the policy that luggage of checked-in passengers who fail to board the flight must be off-loaded for the security reasons. Thus, currently only a small number of bags are delivered on the next flight, and the affected passengers will not be notified until they attempt to collect their luggage at the destination airport. Provided that most or all of the bags are allowed to be delivered on flights other than the passengers' flight, many significant improvements to the AT delivery services can be devised as we will discuss in the rest of the paper. Specifically, the implementation aspects of dissociating passenger travel and baggage delivery are considered in Section 3, and the benefits and future trends are summarized in Section 4.

Consider a single passenger travel from the point of origin (usually the passenger's home, work place, or a hotel in the return journey) to the destination (a hotel, or home in the return journey). The passenger leaves the origin at time T_0 for the departure at time T_1. After the flight of duration $(T_2 - T_1)$, the passenger arrives to the destination at time T_3. Associated to these events at times T_0, T_1, T_2 and T_3 are additional events E_0, E_1, E_2 and E_3 occurring at times $T_0 + \Delta T_0$, $T_1 + \Delta T_1$, $T_2 + \Delta T_2$ and $T_3 + \Delta T_3$, respectively, as depicted in Fig. 2. The events E_i represent:

E_0: baggage sent from the origin to departure airport;
E_1: baggage is delivered to the departure airport;
E_2: baggage is delivered to the arrival airport;
E_3: baggage is collected by the passenger.

In the conventional (current) system, passenger travel and baggage delivery are coupled (synchronized), so that $\Delta T_i = 0$, for all $i = 0, 1, 2, 3$. However, once these two processes become separated, the events E_i, $i = 0, 1, 2, 3$ generally occur before or after the corresponding times T_i (i.e., $\Delta T_i \neq 0$) which allows to consider entirely new AT services with the significantly improved passenger experience.

B. Baggage Delivery Strategies

Even though dissociation of passenger travel and baggage delivery is conceptually simple, its implementation is rather non-trivial, since it is constrained by the strict AT regulations, especially those involving the AT safety and security. Importantly, at all times, baggage ownership has to be defined. In particular, the passengers hand over their baggage to the airline or the airport baggage service before the departure, and then take over their baggage back upon the arrival. Other baggage ownership handovers frequently occur during baggage handling and delivery (e.g., loading and unloading).

Passenger travel involves three segments: journey to and from the airport (ground segments), and the air travel between the departure and destination airports. The passenger and baggage dissociation for the ground segments is specific as it does not involve the air travel. Hence, the 3rd parties may provide a new travel service to deliver passenger baggage to and from the airport. Prior to the departure, the passengers can either drop their luggage off at a dedicated collection point (established, e.g., at a post office, central bus or railway station, by large supermarkets and similar such sites), or their luggage is conveniently collected from their premises. This enables hassle-free passenger travel to the departure airport, encouraging the use of more efficient and ecological public transport. At the destination airport, instead of collecting baggage from the belt in the arrival hall, the 3rd party can again provide a new delivery service for baggage to the selected destination (typically, a hotel) which simplifies passenger

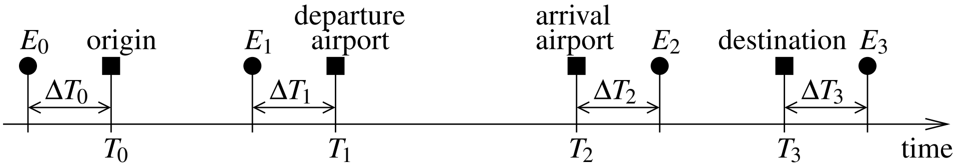

Figure 2. The time axis of passenger travel and baggage delivery between an origin and a destination.

travel from the airport. For instance, the Manchester airport in the UK is experiencing over 40,000 vehicle movements daily, so any consolidation of the travel to and from this airport by means of public buses and trains can greatly contribute to its sustainability.

Dissociating passenger travel and baggage delivery within the air segment is the most complex as it requires changes to the current airline and airport procedures and regulations. On the other hand, unlike baggage dissociation over the ground segment, the required technology and infrastructure is already available at the airports, so the changes are mainly related to baggage handling and logistics. In particular, let $\Delta T_0 = \Delta T_1 = 0$, i.e., the passenger delivers his/her luggage to the departure airport, and check it in with the airline. The airline schedules luggage delivery to the arrival airport. The passenger is notified about the most likely collection time, for example, during the check-in, or even during the air-ticket booking prior to his/her travel to the departure airport. Since luggage is likely to be delivered after the passenger arrival, the airline agrees with the passenger the collection method at the destination. The airline can exploit the delayed luggage delivery to better optimize the profit-paying cargo delivery, especially if sufficient number of passengers sign up for the delayed luggage service, and there is a premium for the expedited cargo delivery. The incentives (e.g., extra travel miles) can be used to manage the demand for this new baggage service. For instance, the passengers can be encouraged to send their luggage to the airport early prior to their travel; according to the airline operational procedures, luggage is usually loaded to the aircraft at least 0.5 hours prior to the departure.

C. Aircraft Load Optimization

In order to assess the feasibility of the proposed dissociated baggage delivery, we consider an AT network segment consisting of an origin airport, a destination airport and a single stopover airport. Similar analysis can be performed for more complex AT network topology having multiple (e.g., stopover) airports by iteratively expanding the model in Fig. 3.

Let there be p passengers traveling from the origin to a destination airport with p_1 passengers on the direct flight, and $p_2 = p - p_1$ stopover passengers. The corresponding baggage volume (e.g., expressed as weight in kilograms) is denoted as $b = b_1 + b_2$, and the cargo volume as $c = c_1 + c_2$. We assume that the passenger numbers p_1 and p_2 on the respective flights are fixed. Provided that the passengers and their baggage can be dissociated, our goal is to optimize loading of each flight.

Denote as L_1 the maximum available load (capacity) for $c_1 + b_1$ on the direct flight, and as L_{21} and L_{22} the maximum available loads for $c_2 + b_2$ on the two indirect flights. Note that there is likely to be more passengers and more load transported on the flights from the origin to the stopover, and from the stopover to the destination than (p_2, b_2, c_2), however, these additional passengers and loads are not included in L_{21} and L_{22}. Thus, we have the constrained loads,

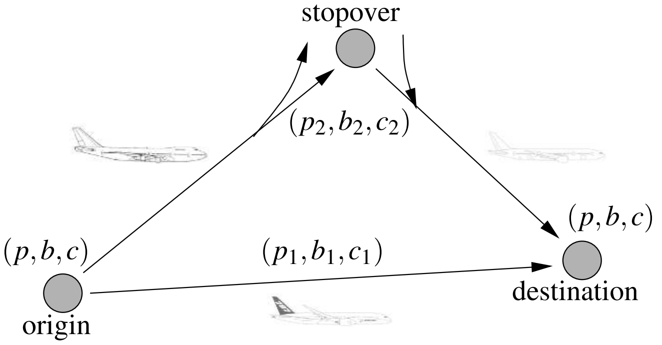

Figure 3. A single origin and destination segment of the AT network with the indicated quantities of passengers (PAX), baggage and cargo.

$$\begin{aligned} b_1 + c_1 &\leq L_1 \\ b_2 + c_2 &\leq \min(L_{21}, L_{22}). \end{aligned}$$

If α_1, α_2, β_1 and β_2 denote the unit transport costs (tariffs per kilogram of weight) of b_1, b_2, c_1 and c_2, respectively, on the corresponding flight segments, we want to minimize the total transport cost:

$$\begin{aligned} & \min\left(\alpha_1 b_1 + \alpha_2 b_2 + \beta_1 c_1 + \beta_2 c_2\right) \\ = & \min\left(\underbrace{\alpha_2 b + \beta_2 c}_{\text{const}} + b_1 \underbrace{(\alpha_1 - \alpha_2)}_{\Delta\alpha_{12}} + c_1 \underbrace{(\beta_1 - \beta_2)}_{\Delta\beta_{12}} \right) \\ = & \min\left(b_1 \Delta\alpha_{12} + c_1 \Delta\beta_{12}\right) = \min M(b_1, c_1) \qquad (1) \\ & \text{s.t. } L_2 \leq (b_1 + c_1) \leq L_1 \end{aligned}$$

where we denoted $L_2 = c + b - \min(L_{21}, L_{22})$. We further assume that the load capacity $L_1 > L_2$, and that the transport costs $\Delta\alpha_{12} < 0$ and $\Delta\beta_{12} < 0$ to meet the transport demands as indicated above.

The problem (1) is a simple linear program with two decision variables b_1 and c_1 given the transport capacities L_1 and L_2, the loads c and b, and the set of costs $\{\alpha_1, \alpha_2, \beta_1, \beta_2\}$. This problem can be readily solved graphically. In particular, the feasible region of decisions (b_1, c_1) satisfying the load constraints is shown as a shaded area in Fig. 4. Provided that $|\Delta\alpha_{12}| < |\Delta\beta_{12}|$, i.e., the tariff differential for baggage

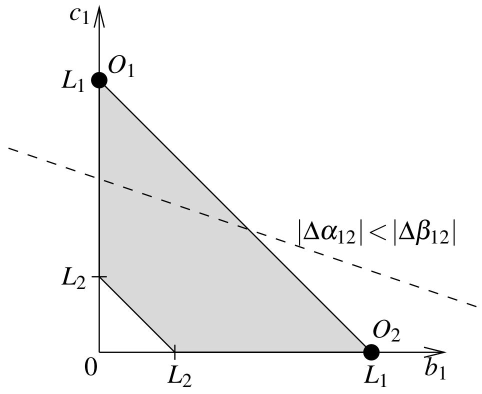

Figure 4. The payload optimization for the direct and stopover delivery in Fig. 3.

delivery between the direct and indirect flights is smaller than the tariff differential for cargo delivery, the optimum solution minimizing the transport cost corresponds to the point O_1 in Fig. 4. The dashed line in Fig. 4 is defined by the expression:

$$c_1 = -\frac{\Delta\alpha_{12}}{\Delta\beta_{12}} b_1 + \frac{M}{\Delta\beta_{12}}$$

and the minimum cost is given by the minimum value of M. On the other hand, if the tariff differentials are such that $|\Delta\alpha_{12}| > |\Delta\beta_{12}|$, the dashed line in Fig. 4 would have the gradient smaller than -1, and the optimum is given by the point O_2. Finally, if $|\Delta\alpha_{12}| = |\Delta\beta_{12}|$, i.e., both types of the loads have the same differential cost, the dashed line in Fig. 4 would have the gradient equal to -1, and any decision contained on the line between the end-points O_1 and O_2 is optimum. However, in practice, the tariffs for baggage and cargo delivery are likely to differ significantly [3]. If the transport capacity $L_1 > c_1$ and the optimum load is given by O_1, the remaining capacity $(L_1 - c_1)$ on the direct flight is used for transporting baggage b or cargo c_2, depending whether the costs $\alpha_1 < \beta_2$ or $\alpha_1 > \beta_2$, respectively. Similar conclusions applies for the optimum O_2 and the non-zero transport capacity $(L_1 - b_1)$.

We can readily generalize the load optimization problem in (1) to more types of cargo. The cargo types are defined by their different transportation tariffs. As shown in the solution of (1), the loads with larger tariff differential are more important and should be considered before the other loads. While still assuming only a single origin and a single destination, we can further generalize the load optimization problem to the case of multiple stopovers. We then minimize the total cost $\sum_{ij} \alpha_{ij} c_{ij}$ over all origin-destination routes i with the cargo loading c_{ij}, for a given set of costs $\{\alpha_{ij}\}$.

Consequently, by dissociating passenger travel from baggage delivery, we can consider baggage to be another type of cargo. This brings a great flexibility to optimize the aircraft loading, since baggage delivery is currently provided on most flights of the commercial airlines.

Table I
SOME FLIGHT STATISTICS BETWEEN SELECTED AIRPORTS

Orig.	Dest.	dur.	direct	1 stop	2 stops	total
EDI	PEK	< 24h	0	42	94	136
DUB	PEK	< 24h	0	49	62	111
LHR	PEK	< 24h	3	103	21	127
EDI	FCO	< 12h	1	27	15	43
DUB	FCO	< 12h	2	43	10	55
LHR	FCO	< 12h	3	80	2	85
EDI	DXB	< 12h	0	52	6	58
DUB	DXB	< 12h	4	63	7	74
LHR	DXB	< 12h	20	102	5	127
EDI	JFK	< 18h	0	89	23	112
DUB	JFK	< 18h	8	66	9	83
LHR	JFK	< 18h	69	141	11	221
EDI	PIT	< 18h	0	4	51	55
DUB	PIT	< 18h	0	30	61	91
LHR	PIT	< 18h	0	156	51	207
EDI	GIG	< 24h	0	9	35	44
DUB	GIG	< 24h	0	7	52	59
LHR	GIG	< 24h	1	42	33	76
EDI	SYD	< 32h	0	6	104	110
DUB	SYD	< 32h	0	17	44	61
LHR	SYD	< 32h	0	93	65	158

D. Initial Implementation Strategy

We consider dissociation of baggage delivery for the air travel segment only in order to outline an initial implementation strategy. We propose to deliver baggage on the flights with the minimum number of hops (stopover airports). Specifically, all baggage should be delivered on the direct flights between the airport hubs, and baggage delivery on the flights with one stopover is preferred to the flights with two stopovers and so on. Tab. I contains the typical numbers of daily flights with up to 2 stopovers, given the maximum overall journey duration (in hours) between the given origin and destination airports denoted by their 3-letter IATA codes[1]. For the three selected origin airports in the UK and Ireland (EDI, LHR and DUB), the destination airports are chosen in the different continents.

As indicated above, we assume a typical airline load of 7-15 tons of checked-in baggage which represents about $1/3$ to $1/2$ of the overall cargo load of 23-28 tons. Consequently, in order to estimate the average number of flights N_{B} required to aggregate baggage delivery (i.e., the baggage load on these flights has priority over the cargo load) over one day, we denote as B the average baggage load per (origin-to-destination) flight, and as C the same quantity, but for the cargo load. Then, $B = \alpha \cdot C$ where typically, the fraction $\frac{1}{3} \le \alpha \le \frac{1}{2}$ (i.e., the higher the average passenger flight occupancy, the larger α), and the flight average load excluding the passengers is, $B + C = (1+\alpha)C$. For the total number of daily flights N_{tot} considered, we have that, $N_{\mathrm{tot}} \cdot B \approx N_{\mathrm{B}}(B + C)$, and thus,

$$N_{\mathrm{B}} \approx N_{\mathrm{tot}} \cdot \frac{\alpha}{1+\alpha}$$

where the function $f(\alpha) = \alpha/(1+\alpha)$ is strictly increasing. For example, $f(1/2) = 1/3$, so about $1/3$ of the daily flights

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[1] Data collected manually from skyscanner.net for a typical week day in November.

between the given origin and destination airports can be used to carry all the daily baggage volume on the remaining $2/3$ of the flights reserved for the cargo (no baggage) delivery. More importantly, these $1/3$ daily flights for the aggregated baggage delivery should be allocated over the routes with the minimum number of hops (stopovers). Moreover, since the flights between the origin and destination airports are usually scheduled over the whole day (except a period after the midnight, say, 12am till 5am), the maximum baggage delivery delay (after the passenger's arrival to the destination airport) is approximately $(24-5)/3 \doteq 6.3$ hours which is acceptable. In practice, this maximum delay is likely to be smaller, for example, when baggage is delivered on the direct flight while the passenger travel includes one stopover. Note also that we assume that the airlines fully collaborate (beyond the current flight share schemes) to better utilize the aggregated baggage transport capacity between the origin and destination airports.

In summary, delivering baggage over the flights with smaller number of stopovers (ideally, via the direct flights only), relieves the baggage load congestion, and thus, increases the load throughput at the stopover airports. We recommend to route baggage over the direct flights only whenever possible (i.e., when the aggregated load on the direct flights is sufficient), and especially when the destination airport is a large air travel hub.

3. IMPLEMENTATION ASPECTS

In general, the implementation strategy is critical to overcome many challenges. The main challenge to enable dissociation of passenger travel and baggage delivery is the security, especially when the 3rd parties become involved by offering new baggage delivery services. The modern X-ray scans can reliably detect any suspicious or prohibited luggage content, so they are nowadays used immediately after the baggage check-in at the airports. However, to resolve the luggage content issue requires on-site presence of the passenger. This may constrain baggage delivery to the departure airport either together with the passenger arrival or earlier, but not later. The X-ray scans at the departure airport are also expected to be used for the remote customs clearances under the import regulations of the destination country [3]. The 3rd party baggage delivery to/from the airport requires additional measures to prevent unauthorized tampering with luggage such as the use of secure lockable transport containers.

The provisioning of the passenger services in AT is often shared by the airport authorities, the airlines and the other 3rd parties. Thus, their coordination using well-defined communication and data sharing protocols and models is important. The added flexibility of the proposed baggage delivery creates opportunities to utilize assets, resources and the infrastructure more efficiently. However, the changes in baggage handling procedures also necessitate new service level definitions (e.g., on-time delivery guarantees and penalty for late delivery), new business models (e.g., new incentives, costs and infrastructure sharing strategies) as well as new supporting services (e.g., real-time anywhere baggage tracking, insurance of the luggage contents and of the agreed on-time delivery).

Dissociation of passenger travel and baggage delivery is likely to be implemented in several phases following the current IATA's phased approaches and roadmaps to significant upgrades of the AT infrastructures and procedures. For instance, Checkpoint of the Future program [3] defines the risk assessment and the required technology and operations for the three implementation phases to be completed by 2014, 2017 and 2020, respectively. The Fast Travel and Bags Ready-to-Go programs of the IATA [11] aim to improve the airport passenger throughput and capacity, especially by focusing to speed-up the baggage check-in processes. Hence, the proposed dissociated baggage delivery is highly relevant to these two programs. In particular, the home check-in is now widely adopted by the airlines and passengers, however, the innovations in the baggage check-in processes have not been considered until recently. Many airlines already have self-check-in kiosks allowing the passengers to print their own bag-tag in order to speed-up the baggage drop-off. Some airlines (e.g., KLM and Qantas) are subsidizing the programmable electronic bag-tags [12], [13], [14]. The electronic bag-tags are reusable, allow smartphone programming, and to some extent a real-time localization of the baggage. Other airlines (e.g., British Airways and Air France) are trialing the cost-effective home-printed bag-tags. These solutions lower operational costs, and provides new revenue incomes to the AT service providers.

The ICCT (Information, Communication and Computing Technologies) are the key enabler of these improvements by providing accurate and trusted information in real-time to wherever it is needed for the timely operational decision making. It is recognized that as much as 97% of the passengers are now traveling with their smartphones [2]. Particularly over the ground segments (to/from the airports), dissociation of passenger travel from baggage delivery is fundamentally dependent on real-time tracking of baggage location. This increases security, enables efficient management of the baggage flows (especially during the unplanned service disruptions), and creates the piece of mind for the passengers. The baggage tracking is likely to be realized as a multi-tier network of tracking devices:

- The low-cost RFID-type chips containing a newly introduced UUID (Universally Unique Identifier) [2] attached to luggage seek as well as can be queried by the nearby access points.
- The access points are aware of their location; they exploit GPS-type tracking when they are mobile (e.g., mounted on the baggage delivery vehicles). The portable (hand-held) access points can be used in case the manual baggage handling becomes necessary.
- The access points periodically report all baggage they have authenticated to the tracking center.

Furthermore, the IATA requires that the airlines track and record all baggage process steps (e.g., delivery, acquisition, transfer, handover, aircraft loading and unloading) since 2018.

4. BENEFITS AND FUTURE TRENDS

The proposed dissociation of passenger travel and baggage delivery contributes directly to the IATA InBag program which is concerned with the baggage processes across the industry [3]. The main objectives are to increase the airport throughput (especially at large busy airport hubs) and improve the passenger experience, and ultimately, baggage dissociation should be over the whole journey (door-to-door). The airport throughput is increased by simplifying and automating the processes and reducing their response times. In fact, the trend of automating the processes in AT is a strong driver supporting the proposed idea of baggage dissociation. The passenger experience is improved by making the services more reliable, more intuitive and more user-friendly while providing the passengers with more autonomy and control. Baggage dissociated from the passengers can be routed more directly to the destination which streamlines its delivery over the AT network. The airlines may collaborate to deliver all luggage several times a day on the dedicated cargo flights, for example, at least among the major airport hubs.

The airlines (the IATA) as well as the airports are likely to support delivery of baggage to and from the airports by the 3rd party forwarders. Such service could be integrated with the existing cargo and parcel AT delivery to exploit the existing infrastructure. This greatly simplifies the check-in process and fully avoids the baggage drop-off at the departure airport. The baggage-free passengers are then much more likely to use public transport to and from the airports, thus relieving the airport traffic congestion. The new baggage delivery is likely to differentiate among several service levels and fee options, for example, to manage delivery priorities. Furthermore, once the dissociated baggage delivery is fully implemented, one has to wonder whether the regulation would require that the passenger travel and their baggage is delivered from the same departure airport to the same destination airport, even though possibly at different times. If such requirement is not adopted, the baggage delivery service will be completely independent of passenger travel (who may well decide not to travel at all), and it will then resemble a courier or parcel delivery service.

The large busy airports now operate close to their capacity while the demand for AT is continuously increasing [2]. Hence, there is a need to completely reconsider the airport designs to reflect the growing demands, and to better accommodate the new regulations and processes as they are being introduced by the IATA [3]. For instance, the new airport design may have passenger-only and baggage-only terminals with the supporting infrastructure optimized accordingly.

Baggage dissociation is also likely to encourage new aircraft designs. The passenger-only aircraft are faster to load and unload, they can either accommodate more passengers, or provide more room for the passengers (i.e., contribute to the passenger experience), and at the same time, they are lighter, and thus faster and more fuel efficient. Such new aircraft designs represent multi-billion opportunities for the aircraft manufacturers such as Airbus and Boeing. Recently, Airbus filed several relevant patents on the new aircraft designs supporting these ideas [15], [16].

Independent baggage delivery can be aligned with the recent proposal on the Physical Internet [17]. The Physical Internet mimics the delivery of data packets by proposing to physically deliver things in the standardized containers. Hence, it is likely that future luggage will be standardized including the shape, size, materials, and accessories (e.g., the wheels and handles for easy moving, loading and storage). Such standardized luggage will have integrated sensors (location, temperature, acceleration) and the recording of the sensor outputs.

Moreover, many sensors will be deployed in the realization of the current IATA programs and visions. Such sensor networks can be considered to support the roll-out of the emerging Internet of Things (IoT).

We conclude that our study outlined in this paper indicates that dissociating passenger travel and baggage delivery is a promising step towards more sustainable future Air Transport.

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