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1. Introduction

Within the BrightSky Mobility Fund research project (WP3.1) TNO has developed a fleet management simulation model for air side baggage transport on the airport Schiphol[1]. It presents a case study on the KLM Ground Services baggage fleet operations that compares different fleet scheduling systems on the KLM baggage tugs operations. Automated fleet management can optimise baggage tug and subsequent airplane turnaround processes on the air side. This optimization can be done on single operator fleet level, but further efficiency increases can be enabled by horizontal collaboration between ground handling vehicle fleets.

To extend this foregoing research, the broader perspective of the different ground handlers on fleet operations and possible fleet collaboration has been researched by interviewing all other 5 Schiphol ground handling operators (next to KLM Ground Services). The main goal was to identify the possibilities for horizontal collaboration on air side baggage transport operations. In parallel, the interviews touch upon related current and future technology and innovations that relate to horizontal collaboration. These topics are fleet management, automation of fleet management, as well as automation of vehicles. Horizontal collaboration can be further enabled by automation of air side vehicles and automated decision making on scheduling of vehicles. It can improve operational efficiency and support sustainable airport operations. Also, topics of sustainable operations and other relevant future trends have been questioned to get a broader ground handler perspective on baggage transport fleet innovations.

This memo outlines the key findings and outcomes from a limited set of 5 ground handler interviews. The purpose of these interviews was to gain a preliminary understanding of the current situation and to address the stated research objectives. It is important to emphasize that the insights presented here are based on a small sample size and therefore lack statistical robustness. As such, the results and conclusions should be interpreted with caution and are not intended to support generalizations beyond the scope of this memo.

The following sections entail a short introduction to the baggage transport context, a summary of the interview findings, and an overall analysis of the broader perspective of the ground handling operators.

2. Context

The interviews with the ground handlers focus on airside baggage transport. This entails the baggage handling operations between airside infrastructure, the baggage handling system, and the airplane stands, and vice versa. At Schiphol Airport, the baggage transport is executed by one of six ground handlers that have a service contract with the airlines. These ground handlers operate a fleet of vehicles and crew that execute the transport process of (un)loading baggage trailers or ULD (Uniform Loading Device) on dollies, towing the trailers or dollies to (and from) the airplane stands and (un)loading the bags (from and) to the airplane. Operationally managing the fleet and crew that executes these operations is a challenging task of scheduling and rescheduling in a dynamic airside environment.

[1] TNO 2024 R11490 Autonomy and self-organisation in airside baggage transport. BrightSky WP3.1

Examples of the dynamics are airplane delays and gate changes. Also, the hub-function of Schiphol leads to high peaks in operational demand due to clustered arrival and departure of airplanes.

In the interviews we discussed with the ground handlers how to manage their operations and which type of technologies they currently use, and foresee to use, to support their fleet management and fleet operations. Note that next to baggage transport operations, the ground handlers also execute more operations to facilitate airplane turnaround, such as pushbacks, staircases, re-fueling, de-icing, power-supply, catering, waste, etc., which are not the primary focus but also concern assets and vehicles that require fleet management and allow for possible collaboration.

3. Interview Findings

3.1. Fleet Management & Efficiency

3.1.1. Task Assignment Methods

Across ground handling operations at Schiphol, task assignment methods vary, ranging from fully manual systems to semi-automated and emerging automated solutions. While some handlers rely on manual allocation by supervisors or floor coordinators, others have adopted or are transitioning to digital platforms such as GroundStar's Realtime or SITA's real-time planning tools. These systems aim to enhance efficiency by matching tasks to employee skills and availability, integrating with airport-wide platforms like Collaborative Decision Making (CDM), and enabling real-time monitoring.

However, even among handlers with advanced systems, full automation remains elusive. The complexity of Schiphol's operational environment, characterized by large distances, multiple baggage drop points, and dynamic flight schedules, necessitates manual control or intervention. For some ground handlers, the Schiphol airport complexity cannot yet be tackled by an automated planning system, and making the assignments schedule is a manual operation. In other cases, coordinators often override system-generated assignments to ensure alignment with Service Level Agreements (SLAs), infrastructure constraints, and real-time disruptions. This hybrid approach reflects a broader trend: while digital tools are increasingly adopted, but are still limited, human oversight remains critical for operational reliability.

3.1.2. Trailer Train Formation

Trailer train strategies are shaped by safety, space constraints, and operational philosophies. Most handlers limit trailer train lengths to four to six trailers, balancing efficiency with maneuverability in congested baggage halls. One handler, for instance, enforces a strict four-cart limit due to increased congestion following the entry of a new market player, which has led to shorter but more frequent trips. Another handler allows six-cart trains but adapts unloading procedures to accommodate space limitations, such as temporarily parking excess carts. Note that also the tug capacities can limit the trailer train length. A supplier limited the length of the train to five trailers due to weight limitations.

3.1.3. Load Balancing, Idle Time and Causes

Handlers with integrated operations, where the same staff and equipment manage both inbound and outbound flows, demonstrate greater flexibility in load balancing. In contrast, handlers with separated ramp and basement teams face more rigid workflows, potentially impacting responsiveness during peak periods.

Idle time is generally minimized through proactive planning and real-time coordination. Handlers with stable flight schedules benefit from predictable workloads, allowing for efficient resource allocation and minimal downtime. During off-peak hours, staff are often redirected to preparatory tasks, such as organizing containers or pre-positioning equipment.

However, during peak periods, idle time can increase due to staffing shortages, equipment breakdowns, or infrastructure bottlenecks. Some handlers mitigate this by deploying cross-trained teams, reallocating equipment dynamically, or leveraging predictive tools to anticipate workload surges. Others rely on informal support from peer handlers or draw on flexpools shared across the airport.

3.1.4. Staffing Challenges and Peak Hour Strategies

Staffing remains a persistent challenge, particularly during peak hours. Budget constraints, seasonal fluctuations, and the physical demands of baggage handling contribute to workforce instability.

Handlers employ various strategies to address these issues:

- **Dynamic Planning**: Pulling tasks forward or reallocating staff based on real-time needs.
- **Cross-Training**: Enabling staff to switch between ramp and basement roles or between baggage and cargo operations.
- **Flexpools**: Participating in shared pools of temporary workers to absorb demand spikes.
- **Predictive Tools**: Using capacity planning systems to forecast workload and optimise staffing levels.

Despite these efforts, some handlers report that equipment shortages and infrastructure limitations can still hinder peak hour performance, underscoring the need for systemic solutions.

4. Future Collaboration Potential

4.1. Existing Collaboration

Collaboration among handlers at Schiphol is currently limited and largely informal. Equipment exchange, such as tugs, belt loaders, or charging stations, occasionally occurs during emergencies or peak periods. Some handlers have formalized these arrangements through contracts, enabling rapid support and mutual assistance. Handlers mention that there is also informal use of each other assets, examples concern use of each others baggage trailers or dollies for airplane containers

Some of the handlers have established partnerships for equipment pooling, staff sharing, and joint operations with other service providers. These collaborations are often facilitated by shared goals around safety, efficiency, and sustainability. As stated above these pooling initiatives are mostly driven by operational continuity in case of limited available equipment and ground handlers note that the collaboration are always minimal to minimize support to competing businesses.

4.2. Perceived Benefits and Challenges of Fleet Sharing

The potential benefits of fleet sharing are widely acknowledged:

- **Space Optimization**: Reducing the number of idle vehicles in congested areas.
- **Cost Efficiency**: Lower capital and maintenance costs through shared ownership.
- **Sustainability**: Fewer vehicles mean reduced emissions and improved airside safety.

However, significant challenges persist:

- **Standardization**: Variations in equipment types, container sizes, and loading systems hinder interoperability.
- **Maintenance and Liability**: Questions about responsibility for repairs, damage and insurance complicate shared use.
- **Operational Autonomy**: Handler's fear of losing control over service quality and responsiveness.
- **Brand Differentiation**: Uniforms, equipment branding, and service models are seen as competitive differentiators.

Some handlers are open to a neutral pooling model managed by Schiphol or a third-party provider, provided that governance is transparent, and operational control remains balanced. Frankfurt Airport is frequently cited as an example of such a model.

4.3. Legal, Contractual, and Operational Barriers

Legal and contractual frameworks pose some of the most formidable barriers to collaboration. Each handler operates under unique SLAs with airlines, which dictate specific handling procedures, performance metrics, and data privacy requirements. These agreements often preclude cross-handler task execution or equipment use.

Operationally, differences in ground handling manuals, safety protocols, and staff training, further complicate integration. Even when collaboration is technically feasible, cultural differences and frontline resistance can undermine implementation. Without standardized rules and airport-level coordination, deeper collaboration remains aspirational.

4.4. Airplane Turnaround Coordination

Turnaround operations are currently siloed, with each handler managing its own assignments with its own equipment. While some handlers support the idea of more centralized asset pools, especially to facilitate shared equipment use, others express concern about losing control over service prioritization. Diverging priorities between different stakeholders, such as Schiphol (focused on punctuality) and airlines (focused on transfer efficiency), could further complicate coordination.

Shared buffer systems or pooling of platform assets could enhance efficiency but would require robust governance and stakeholder alignment.

5. Plans & Trends

5.1. Handler Visions for Future Operations

Ground handlers at Schiphol are actively preparing for a future shaped by automation, electrification, and infrastructure modernization. Common themes include:

Electrification: Most handlers have already transitioned to fully electric baggage fleets, with only a few diesel units remaining for specialized equipment, mainly pushbacks. Charging infrastructure is limitedly available and is unevenly distributed over the different handlers, leading to informal sharing.

Automation: Several handlers are piloting or planning to implement autonomous systems, including AGVs, AI-powered monitoring tools, and automated planning platforms. These initiatives aim to reduce physical strain, improve efficiency, and support data-driven decision-making.

Infrastructure Modernization: Handlers are involved in long-term planning for new facilities, such as the Bagagekelder Zuid, which is designed with automation and smart systems in mind. However, legacy infrastructure, especially in older baggage halls, remains a significant barrier to innovation.

5.2. Interest in Automation, Electrification, or Shared Systems

Automation: Trials with autonomous vehicles, lifting robots, and AI-based monitoring systems are underway. While promising, these technologies face challenges related to sensor reliability, connectivity, and integration with mixed traffic environments.

Electrification: The transition to electric fleets is nearly complete across handlers. However, technical limitations persist for certain equipment types (e.g., de-icing trucks, air start units), and concerns remain about the reliability of newer electric models. Also there is discussion on the standardization of charging infrastructure, on the type of charging plug.

Shared Systems: There is cautious optimism about Schiphol managing centralized systems for fleet and turnaround planning. Handlers emphasize the need for clear rules, neutral governance, and respect for airline-specific requirements.

6. Analysis and Discussion

6.1. Automated Scheduling: Promise vs. Practice

Automated scheduling is a central theme in the modernization of ground handling operations at Schiphol. Several handlers have either implemented or are in the process of adopting automated task allocation systems, such as GroundStar's Realtime Control or SITA's real-time planning tools. These systems promise efficiency gains through optimized resource allocation, real-time visibility, and reduced manual intervention.

As also described at 3.1, in reality it is much more nuanced. Despite the availability of automation tools, full reliance on them remains limited. The complexity of Schiphol's operational environment, marked by long distances between gates, variable flight schedules, and infrastructure constraints, often necessitates manual overrides. For instance, one handler noted that while their system works well at a smaller airport, the system is challenged at Schiphol due to its scale and unpredictability. This highlights a critical gap between technological capability and operational applicability.

Moreover, some handlers still rely entirely on manual scheduling, citing the need for human judgment in balancing workloads, managing physical strain, and responding to real-time disruptions. Even among those with automated systems, coordinators frequently intervene to ensure compliance with SLAs and to address unforeseen issues such as equipment breakdowns or staffing shortages.

6.2. Similarities and Differences Across Handlers

Despite operating under different organisational structures and serving diverse airline clients, handlers at Schiphol share several operational similarities:

- **Electrification**: All handlers have made significant strides in transitioning their baggage fleets to electric vehicles, with most reporting near-complete electrification.
- **Manual Overrides in Automation**: Even with advanced scheduling tools, manual intervention remains a common practice.
- **Infrastructure Constraints**: All handlers cite limitations in baggage hall layouts, charging infrastructure, and space availability as barriers to efficiency and innovation.
- **Scepticism Toward Full Collaboration**: While informal cooperation exists, most handlers are cautious about deeper integration due to concerns over autonomy, branding, and contractual obligations.

However, key differences also emerge:

- **Staffing Models**: Some handlers maintain strict separation between ramp and basement teams, while others adopt integrated staffing models that enhance flexibility.
- **Collaboration Attitudes**: A few handlers pursue partnerships and equipment pooling in case of need, while others remain more reserved, emphasizing brand identity and operational independence.
- **Technological Readiness**: The level of automation and digital integration varies widely, with some handlers already piloting autonomous vehicles and others still relying on manual planning.

6.3. Limited Tools for Automated Scheduling

The limited effectiveness of current automated scheduling tools stems from several factors:

- **Infrastructure Mismatch**: Many baggage halls were designed for single-handler operations and lack the standardized layouts needed for automation.
- **Data Fragmentation**: Without centralized data sharing, automated systems operate in silos, reducing their predictive accuracy and responsiveness.
- **Human Factors**: Automation tools often fail to account for nuanced human decisions, such as adjusting for employee fatigue, equipment quirks, or real-time disruptions.
- **System Limitations**: Some systems lack the flexibility to accommodate the diverse SLAs and operational procedures of different handlers, leading to inefficiencies or misallocations.

These limitations underscore the need for more adaptable, context-aware systems that can integrate with airport-wide platforms and support collaborative decision-making.

6.4. Incidental Collaboration: A Patchwork of Support

Current collaboration among handlers is largely incidental and reactive. Equipment is occasionally shared during emergencies, and some handlers informally share charging stations when capacity allows. Some handlers have formalized these arrangements, enabling rapid support during peak periods or equipment failures. Also, multiple handlers underline that there is a limit to collaborating with and supporting a business competitor.

However, these collaborations are often ad hoc and dependent on personal relationships or immediate necessity. There is little evidence of sustained, strategic cooperation. This fragmented approach limits the potential benefits of resource pooling and creates inefficiencies, such as duplicated assets and underutilized capacity.

6.5. Risks and Barriers to Collaboration

The path to deeper collaboration is fraught with risks and barriers:

- **Contractual Constraints**: Each handler operates under unique agreements with airlines, which define service levels, handling procedures, and data privacy requirements. These contracts often preclude shared operations or equipment use.
- **Operational Incompatibility**: Differences in equipment types, safety protocols, and staff training make standardization difficult.
- **Liability and Accountability**: Shared equipment raises questions about maintenance responsibilities, damage liability, and insurance coverage.
- **Cultural Resistance**: Frontline staff may resist collaboration due to perceived threats to job security, identity, or operational control.
- **Governance Ambiguity**: Without a clear, neutral authority to manage shared resources, disputes over access, prioritization, and accountability are likely.

These challenges are not insurmountable but require coordinated action, transparent governance, and a shared vision for the future of ground handling at Schiphol.

6.6. Advantages of Collaboration: A Buffer Against Peak Hour Strain

While most handlers report that current peak hour operations are manageable, they acknowledge that unexpected disruptions, such as equipment failures or sudden staffing shortages, can quickly overwhelm capacity. This is due to the fact that handlers schedule assets and crew for the scheduled, expected, peaks. Disruptions can lead to additional unexpected peak load. In such scenarios, collaboration might provide additional capacity buffers.

Shared equipment pools, cross-handler staff support, and coordination between ground handlers could enhance resilience. For example, one handler described how rapid equipment exchanges with peers helped maintain service levels during breakdowns. Another emphasized the value of staff sharing agreements in absorbing peak demand.

6.7. Sustainability: Electrification and Its Limits

Sustainability is a shared priority across handlers, with electrification at the forefront. Most baggage fleets are now fully electric, and charging infrastructure is generally in place. However, challenges remain:

- **Fossil Fuel Holdouts**: Certain equipment types, such as de-icing trucks, air start units, and high loaders, remain diesel-powered due to technical limitations or lack of viable electric alternatives.
- **Charging Infrastructure Disparities**: Access to charging stations varies significantly between handlers. Some benefit from integrated infrastructure, while others rely on informal sharing due to space constraints or insufficient capacity.
- **Battery Swapping Limitations**: Incompatibilities in battery design (e.g., lack of lateral swapping capability) hinder shared use and centralized charging solutions.

These issues highlight the need for coordinated infrastructure planning and standardization, potentially led by Schiphol or a neutral third party.

6.8. Autonomous Vehicles: Promise and Pitfalls

Autonomous vehicles (AVs) represent a promising frontier in ground handling, with several handlers participating in trials involving AGVs, autonomous tugs, and robotic lifting systems. These technologies offer potential benefits in terms of labour efficiency, safety, and data-driven optimization.

However, critical challenges remain:

- **Infrastructure Readiness**: Schiphol's infrastructure, characterized by varying layouts, narrow corridors, and limited buffer zones, is ill-suited for AV deployment.
- **Mixed Traffic Complexity**: The coexistence of cargo, cleaning, engineering, and passenger transport vehicles creates dynamic environments that challenge AV navigation.
- **Sensor and Connectivity Issues**: Trials have revealed problems with sensor sensitivity and network reliability, particularly in older baggage halls.
- **Standardization Gaps**: AVs require consistent equipment dimensions and loading systems, which are currently lacking across handlers.

Despite these hurdles, handlers remain cautiously optimistic. Some advocate for dedicated AV zones or infrastructure upgrades to support gradual integration. Others stress the importance of semi-automated solutions, such as AI-powered monitoring tools or modified belt loaders, as interim steps toward full automation.

7. Conclusion

The current ground handling operations at Schiphol Airport reveals a sector that is both operationally mature and technologically fragmented. While each handler demonstrates a strong commitment to safety, efficiency, and service quality, collaboration across organisations remains limited. This is not due to a lack of willingness, but rather the result of embedded structural and contractual barriers. The ground handlers are business competitors and therefore have minimal to no incentives to collaborate and support each other's operations.

One of the most significant impediments to collaboration is the diversity of SLAs that handlers maintain with their respective airline clients.

These contracts often include specific operational procedures, performance metrics, and data privacy clauses that make cross-handler cooperation complex. Additionally, the absence of a neutral coordinating authority means that even when collaboration is desired, there is no clear framework to govern shared responsibilities, resolve disputes, or ensure equitable access to pooled resources.

Fleet management practices further illustrate the uneven pace of modernization. While some handlers have adopted digital scheduling tools, the majority still rely on manual task allocation. Even where automation exists, it is often constrained by the need for manual intervention due to the operational complexity of Schiphol's layout and the limitations of current systems. The lack of a unified, airport-wide scheduling platform exacerbates this fragmentation, preventing the realization of potential efficiencies through coordinated planning.

Despite these challenges, there is a shared vision among handlers for a more sustainable and technologically advanced future. Electrification of baggage fleets is nearly complete, with most handlers operating fully electric vehicles. However, the transition is not uniform. Some specialized cargo and support vehicles remain reliant on fossil fuels, and disparities in charging infrastructure, both in terms of availability and spatial distribution, pose ongoing operational challenges.

Interest in automation is also growing. Trials involving autonomous guided vehicles (AGVs), AI-powered monitoring tools, and semi-automated equipment are underway. Yet, full-scale deployment remains a distant goal. Infrastructure limitations, such as inconsistent layouts and the lack of standardized equipment, continue to hinder progress. Moreover, the complexity of mixed traffic environments and the sensitivity of autonomous systems to environmental conditions further complicates implementation.

In summary, ground handler operations on Schiphol air side are individually organized to optimise service to air lines and incidental collaboration occurs to provide continuity. Automated scheduling is in development and automatic vehicles is being explored but both have their challenges for full operational implementation. Sustainability in the means of ground handler asset electrification is showing significant advancement.