AIRCRAFT INTERIOR SYSTEMS FOR THE FUTURE ONBOARD SERVICES IN THE FLYING-V

Master thesis

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Preface.

Flying is the dream of mankind that has come true. It made us being able to see our beautiful planet from above, to visit places beyond our imagination and to reach irreplaceable destinations like home. However, we must act on the severe climate issues and scarcity of fossil fuels. We must change the way we fly. Therefore, I feel honored to be a small part of the Flying-V research project towards a better future. This graduation project challenged me - as it should - and I genuinely enjoyed every part of it. I feel lucky to have learnt so much new and got to meet all these interesting people.

I want to express my sincere gratitude to my supervisory board for taking me on board of this incredible *voyage*; thank you Peter, for your motivational enthusiasm and opening up opportunities for me. Special gratitude to Robin, for your commitment and sharing your knowledge with me. I could not have done this without your outstanding mentorship and guidance through the project.

Special thanks to Mark Broekhans, Roelof Lammers and everyone else from KLM Royal Dutch Airlines, who helped me achieving this final result by offering their time and expertise, again and again. I also want to thank Tom Schreuder from Safran Cabin for sharing his feedback and giving me the necessary understanding of the industry.

This project also enabled me to explore an unknown dimension, and so, I have discovered the possibilities of Virtual Reality. The translation of my design into a virtually accessible cabin environment could not have been realised without the help from the amazing experts at the VR Zone and my friend Jesse: thank you!

Not to forget: a shoutout to everyone who participated in my user tests! I retrieved the greatest insights because of your critical feedback.

Last but not least, I am thankful for my dearest family and friends who had to hear me going on and on and refuel me when needed. Thanks Micha, for your unconditional support and having faith in me.

So we may not change today, but we can change the future. Welcome aboard of the Flying-V!

Tinie Lam.

Executive summary.

The Flying-V is a unique concept aircraft to fly more energy efficient. With the V-shape passenger cabin integrated in its wings, a new interior is created with four different seat concepts. This raises the question of how the onboard services could be designed for the Flying-V. As a matter of fact, food plays an influencing role on the overall flight experience. The main objective of this project is to develop a vision for 2050 on the future onboard services and create a concept that delivers an improved food and flight experience to the passenger.

As consumerism becomes more experience-oriented and the world around us, including the cabin high in the sky, turns fully digital, the demand for customisation grows. Meanwhile, sustainable awareness increases and plays an inevitable role in any future, yet there is a lot of food and cabin waste. An in-depth research was conducted to have a good understanding of the industry, including the airline perspective, the equipment manufacturer and the catering process behind the scenes. From these different domains, several experts have been consulted and a co-creation session has been held with eight cabin crew members and cabin designers. The generated insights are synthesized with the theoretical literature findings into potential improvements and opportunities to design for 2050. Cues for enabling an improved food experience on board deriving from these insights, are flexibility, interaction and digital connectivity. With this understanding, a future vision is formulated and a design goal has been set for the project.

The future is custom-made

This research generated the goal to design a concept wherein passengers are served custom-picked meals, provided at flexible times. This should be carried out in a smart and sustainable manner that supports human interaction.

LOOP: The extended in-flight dining experience

With this vision, a new value proposition for the onboard services is developed. The principle of serving passengers in multiple meal rounds, allows the passenger to decide on board in which moment they would like to have their meal. Another added value is serving out per course, enabling a prolonged dining experience. The meal service rounds are coordinated by the cabin crew in a digital manner.

Passengers can make use of a self-service buffet for beverages, giving them a sense of control that contributes to the food - or in fact, drink - experience. The self-service and digital system reduces the workload and at the same time, the personal contact between crew and passenger. This is compensated by the service per course in each round, which regenerates plentiful moments of interaction in a personal but efficient manner.

Validation

Finally, the designed concept has been evaluated with passengers, cabin crew and cabin experts. The cabin environment is simulated in Virtual Reality, which is used to acquire deeper insights regarding the whole interior experience. The gathered input is consolidated in the final conclusion, including recommendations and reflections, that should be further explored in the future.

Glossary.

Galley
Compartment facility in the aircraft for food service where the food and beverages are prepared and stored

In-Flight Entertainment (IFE)
Audio and video entertainment programmes offered during the flight, usually via a fixated screen in the headrest

Monument
A fixed area within the floorplan of an aircraft, designated for e.g. lavatories or galleys

Onboard Services (OS)
Services provided by the cabin crew on board of an airplane during the flight, namely food and drinks service

Outstation
The caterer's division on the destination of the flight

Pax
Passenger(s)

Turnaround
The aircraft servicing process while it is on the ground, including the unloading and loading of the entire aircraft within a specific time frame

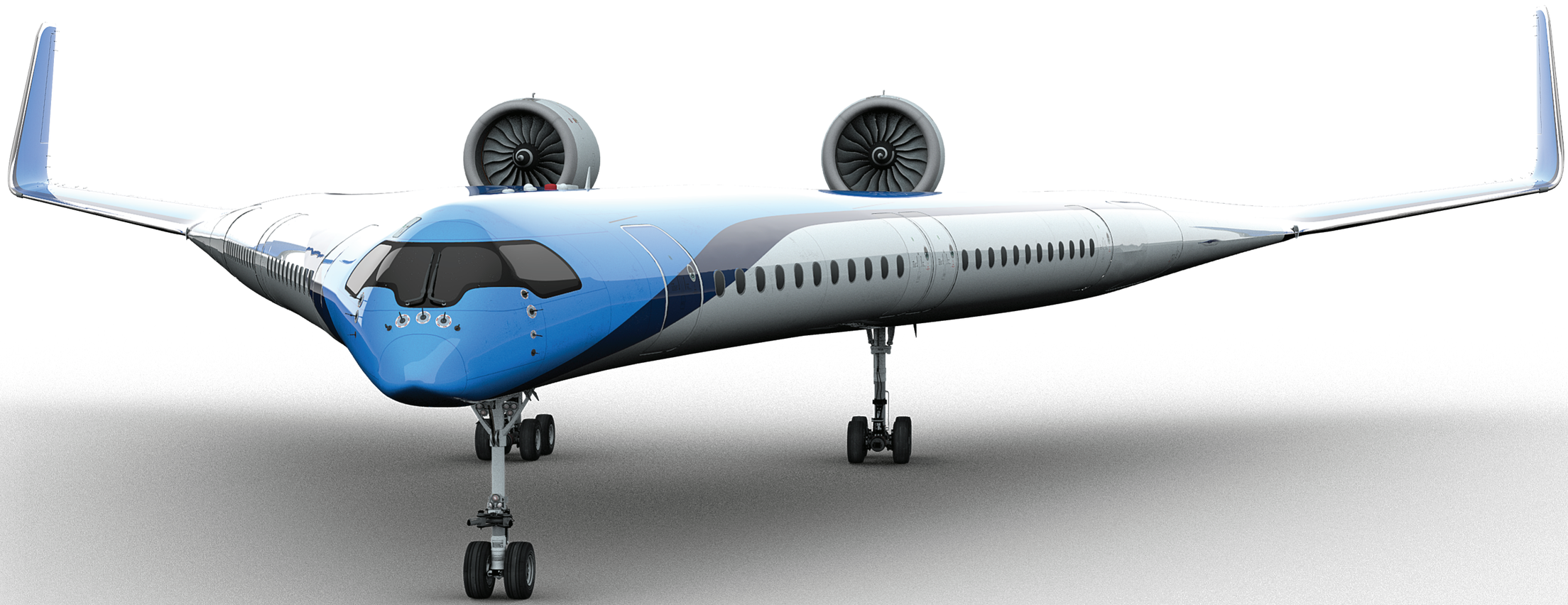
How to read this report
Important aspects and concluding take-aways of a chapter are respectively highlighted or summarized and presented in a coloured block.

↘ **Methodology**
Additional information about a specific design methodology are referred to with an ↘

Supporting materials as data or supplementary information in the appendix, are referred to with an ▶

Content.

1 Introduction



1.1 Flying-V introduction

The Flying-V

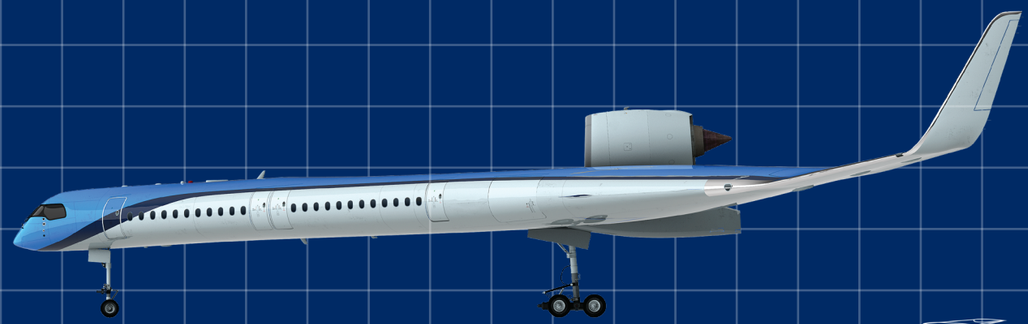
Together, the faculties of Industrial Design Engineering and Aerospace of Delft University of Technology, KLM and Airbus are working on a new long-haul aircraft: the Flying-V (TU Delft, 2020). The Flying-V is a new energy efficient concept aircraft for long-haul flights. Currently, air transport accounts for around 2% of the 36 billion tonnes of carbon dioxide emission that is anually produced by us human beings (Clean Sky, n.d.) and proves therefore an urgent need for a more fuel-efficient aircraft to slow down consumption of scarce fossil fuels and cut down harmful emissions. Originally an idea of TU Berlin student Justus Benad during his thesis project at Airbus Hamburg in 2014, the Flying-V is now being further developed at Delft University of Technology and Airbus.

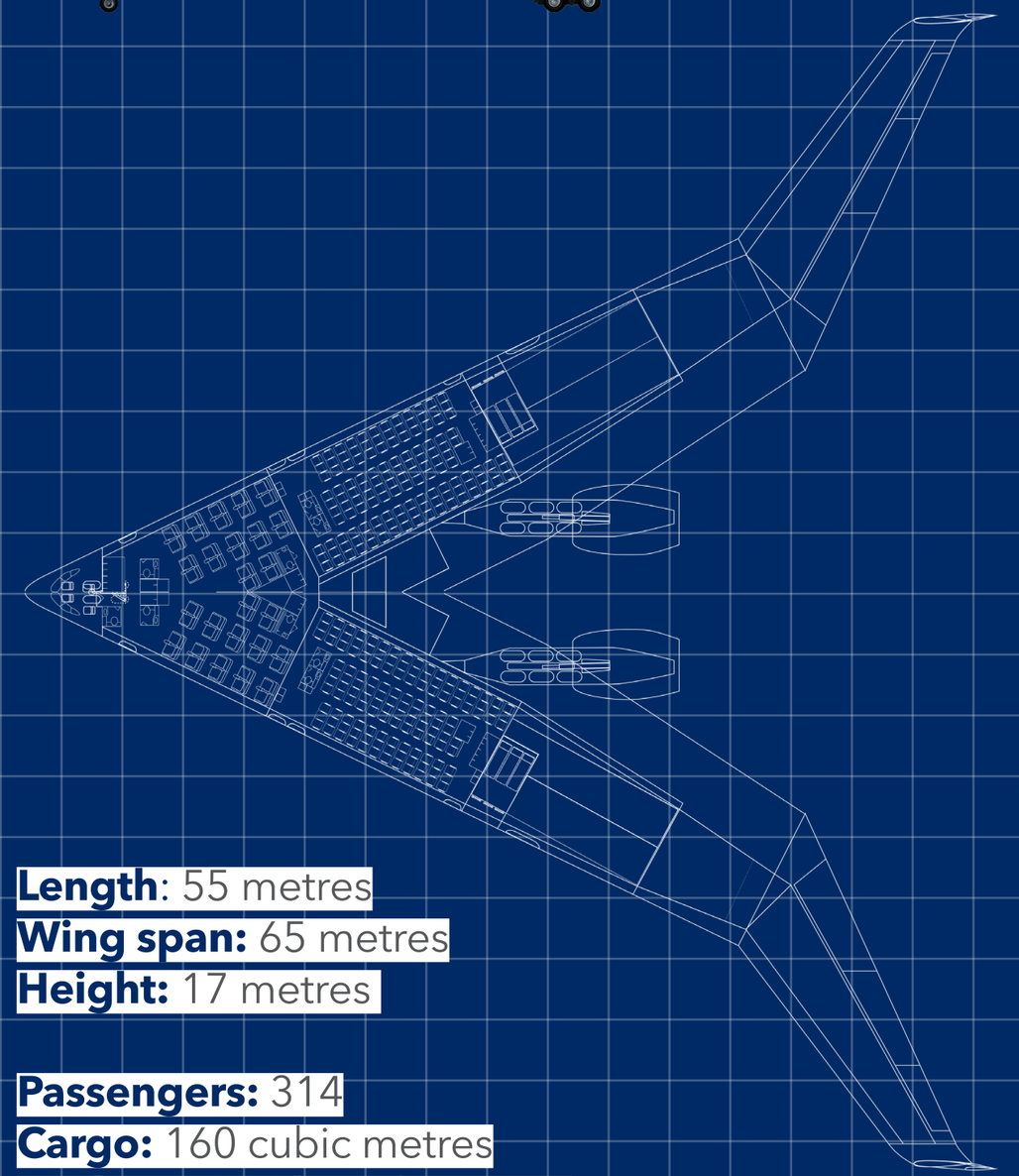
The aircraft's design integrates the passenger cabin, the cargo hold and the fuel tanks in its wing structure, resulting in a distinctive v-shape (TU Delft, 2020). With approximately the same wing span as the Airbus A350 - which is 65 metres - the aircraft can use the present-day infrastructure and its gates and runways, increasing the viability by reducing required investments. Similar to a conventional airplane as the A350, the Flying-V carries about 314 passengers (in a standard configuration) and can be loaded with the same cargo volume, which is 160 cubic metres. Although the loading of the Flying-V is equal to the A350, the aircraft has a lower air resistance with its remarkable form that creates a considerable aerodynamic advantage. This will mean a reduction of 20% in fuel consumption compared to the Airbus A350, which is considered to be today's most fuel efficient airplane. Next to the development of the Flying-V using traditional kerosene engines, alternative ways of propulsion will be studied in the future like hydrogen or e-kerosene (Vink et al., 2020).

Aircraft interior

Its unique V-shape opens up new possibilities for the aircraft interior. With the cabin in its wings now, the interior can be uniquely adapted to sitting inside the wings. The resulting cabin has an oval shape cross-section. An oval shape would actually deform to circular when pressurized at high altitudes, as is the case for aircrafts. In order to prevent this from happening, a rectangular frame is positioned in the oval cabin (Vos, Geuskens & Hoogreef, 2012). This rectangle provides a cabin width of 6.00 metres and a cabin height of 2.15 metres to design a new interior for.

The goal of the Flying-V interior design is to improve passenger experience at lower weight and with similar or higher passenger density. The development of the interior concept is driven by passenger comfort, which is key in user acceptance of transportation systems and highly related to the passenger satisfaction and willingness to fly again (Li, Chu, Gou & Wang, 2018). A new interior has been designed with various seating concepts for different styles of travelling in economy class (TU Delft, 2020).





Length: 55 metres
Wing span: 65 metres
Height: 17 metres

Passengers: 314
Cargo: 160 cubic metres
Fuel: 140.000 litres kerosene

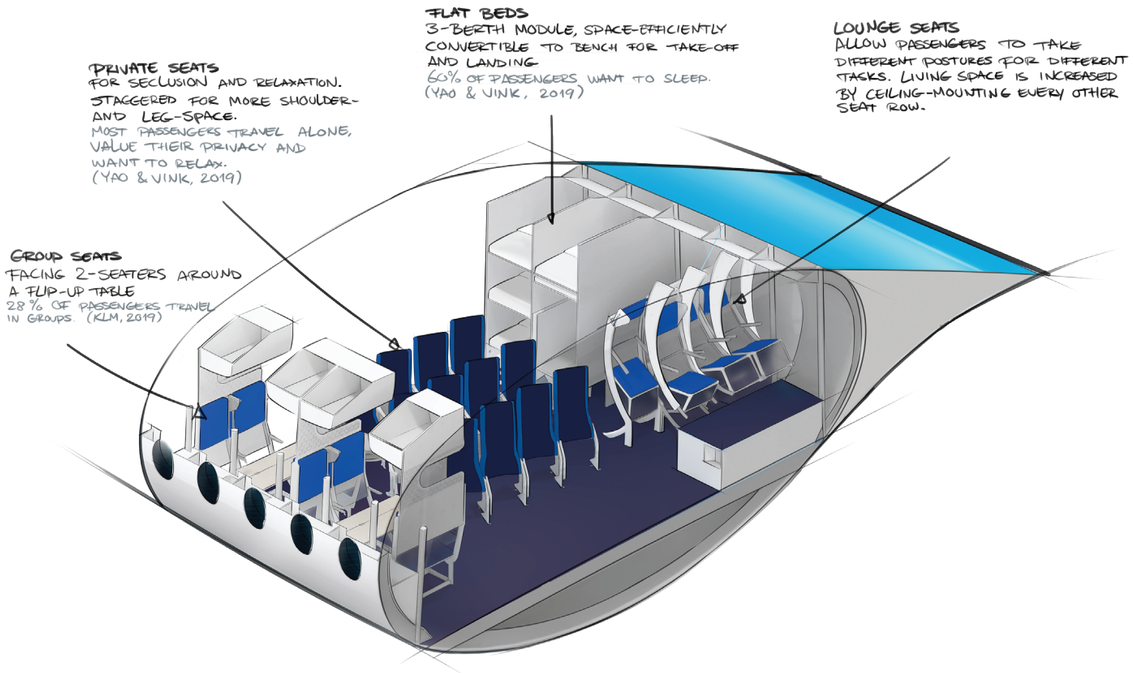


Figure 1
Arrangement of the four seat concepts in section view of the Flying-V right wing

Staggered individual seats
Due to the angle of the cabin to the direction of flight, a fundamental change with respect to conventional airplanes is implemented in the unconventional v-shaped aircraft design. Staggering is done by placing each individual seat in the direction of flight, while keeping seat rows perpendicular to the cabin. As the wing has an angle of 26 degrees with respect to the direction of flying, the seats have the same angle with respect to the oval tube. These seats are intended for individual travellers, who are the larger part of the passenger list. With the seats in an angle, the passenger has more shoulder- and legspace and the elbow armrests are in a position that does not conflict with the neighbour.

Sleeping beds
While 60% of the passengers wishes to sleep during a long-haul flight, it has not been possible to book a bed in economy class before. Beds are costly and inefficient for aircraft interiors. The flat beds in the Flying-V are convertible to benches so passengers are safely seated during take-off and landing, without taking more space than three regular single seats in a row.

Chaise longues
Also chaise longue seats are available for economy class in the Flying-V. Living space is increased by using the space in vertical direction, allowing the passengers to recline the seat and take different postures with the same space needed for regular seat rows.

Group seats
Over a quarter of the passengers travels in a group and are targeted by the group seats which are well-known in train interiors. In this way, passengers travelling together can face each other.

These four innovations are being further developed. It remains unknown to what extent, and how specifically, current regulations should fit this unconventional aircraft design (Vink et al., 2020). The assumption is that the implementation of these four concepts in the Flying-V, would mean a redundancy of other travel classes and thus a complete replacement of the existing class division of economy, (premium economy,) business and first class.

This assumption is the starting point for further exploration, research and concept development of the onboard services in this thesis.

1.2 Project introduction

Onboard Services

As is described in the previous paragraph, the future of the Flying-V will bring fundamental changes to its interior. However, this has consequences for the onboard services. In other words, what will be the new limitations and possibilities? It is not only a practical matter. Exploration and research in future (technological) developments is required to open up new possibilities. The important question is, what does the future of in-flight services look like and more specifically, what will the in-flight dining experience look like in the Flying-V? Onboard Services (from now on referred to as OS), is a broad term for the services offered on board to passengers including food catering and dutyfree sales. The focus of this graduation project is on the in-flight catering aspect. With the radically changed interior as an inspirational source, also other trends in services will be used to design a future concept. A holistic view is needed in order to create an in-flight food concept which incorporates the complete passenger journey from booking a ticket to deboarding the airplane.

Project scope/objective

To explicate the broad scope of OS, a couple of elements are described which play a role in OS and where the project will be built on. The influence of the conceptual seat arrangement of the Flying-V will be taken into account. However, the details of the aircraft configuration will stay on the background, with the primary aim of this project to develop an in-flight food concept on the foreground.

Passenger
In this graduation project, a human-centered design approach will be applied with the goal to develop an inclusive and functional future design (vision).

System
To create an inclusive design as an outcome, the scope of this project goes beyond the passenger and crew. With a holistic view on the ecosystem, the operational process of in-flight services will be studied in order to create a solution that is relevant for the industry.

Cabin interior
The project is concentrated on the functional design of the OS, though outcome of this graduation should consider the aesthetic appearance in relation to its cabin environment as well.

The following research questions will be answered in this graduation thesis:

How and to what extent is in-flight catering designed and performed in relation to its (cabin) environment?

a. What is the role of in-flight food and its effect on passengers?

b. How is the current process and operation of in-flight catering defined?

In what way and form should the onboard services be designed in the Flying-V to deliver an improved food and flight experience with respect to the cabin environment?

a. What is the air travel context of 2050?

b. What are stakeholder's concerns in this future context?

Project layout

The first phase of this assignment is to formulate a vision on the onboard services of the Flying-V in order to create an interior concept that improves the food and flight experience. First, insights on the current onboard services as well as future concepts are gathered by the consultation of the relevant stakeholders and involved parties of the catering, see figure 3. Future possible technologies and consumer trends will also be explored and investigated, whilst passengers and cabin crew will be studied to have an overview of different needs and preferences. With the outcome of these analyses, a vision is compiled with a list of requirements, serving as a guideline for the concept phase that follows.

Involved parties

Besides the involvement of KLM Royal Dutch Airlines as partner of the overall Flying-V project, several experts from various departments within the airline industry are consulted to gather in-depth knowledge about the relevant topics around OS. On a side note, the outcome of this graduation is considered to be projectable on any arbitrary airline and not being restricted to a specific company as KLM Royal Dutch Airlines nor Airbus. For the understanding of the cabin environment regarding equipment, the expertise of Airbus and SAFRAN Cabin Design & Innovation Studio are consulted.

How and to what extent is in-flight catering designed and performed?

- Literature study
- Co-creation with stakeholders
- Analysis of the current process
- Exploration of future opportunities

Design vision & guidelines

In what way and form should the onboard services be designed in the Flying-V?

- Ideation of concept directions
- Development of concept idea
- Conceptualisation (in Virtual Reality)
- Validation
- Iteration & recommendations

Figure 2
The project structure in the total assignment.

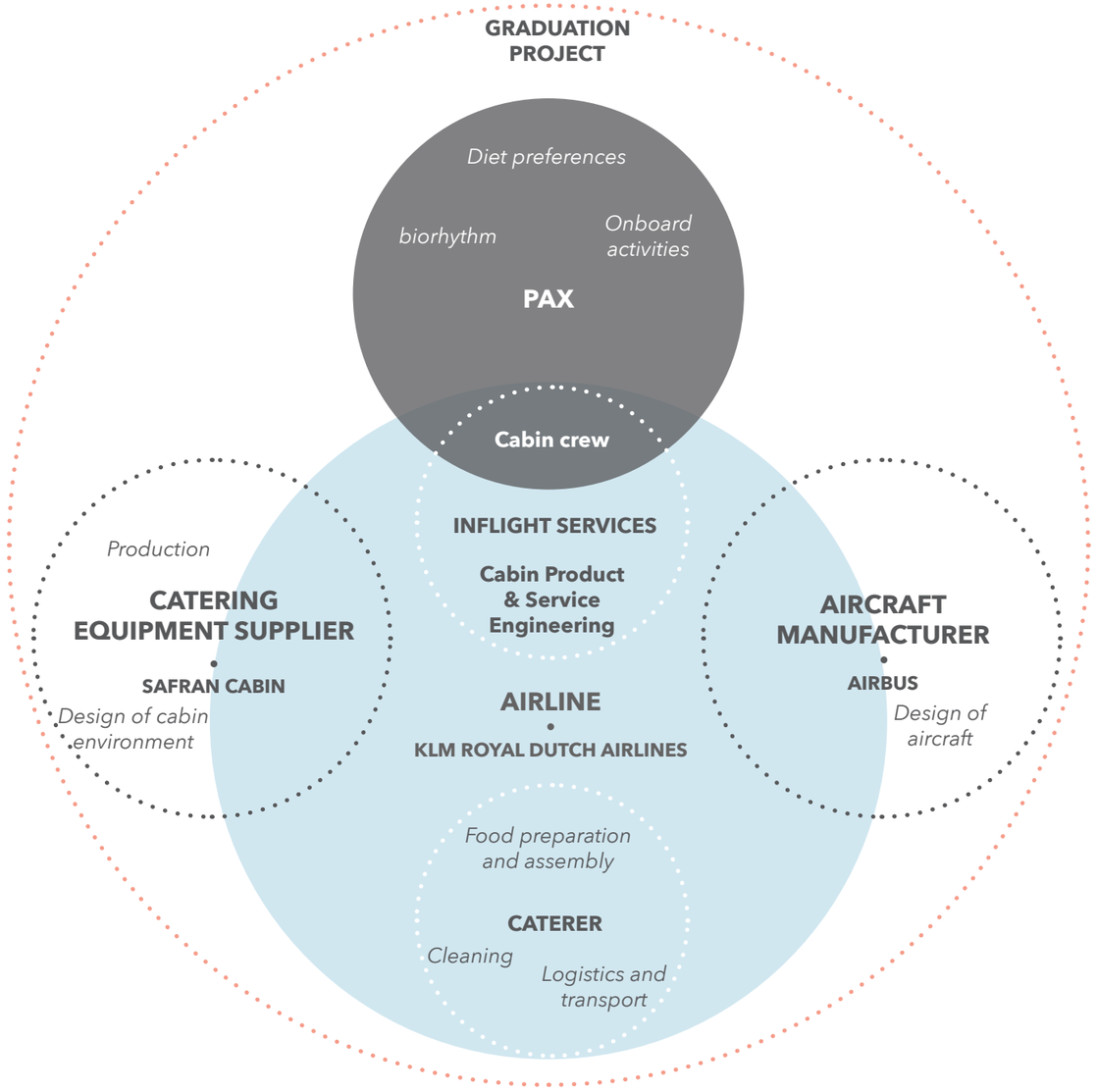


Figure 3
The involved parties are represented by their relation and influence in and around this project.

2 Theoretical background

2.1 The in-flight catering process

Airline catering companies are not only producing meals – they have developed into providers of complete in-flight service solutions and managers of complex supply chain and logistic processes, making flight catering probably one of the most complex operational systems in the world (Jones, 2004). An example: a single, long-haul Boeing 747 has over 40.000 items loaded on to it before it flies. These items varying from meals to toiletry items, from first aid kits to headsets, weigh 6 metric tonnes altogether and occupy a space of 60 cubic metres.

In order to have a broad understanding of this complex operational system, a literature study is done to provide insights from the theoretical aspect. However, to add a practical viewpoint, an interview is conducted with a KLM's Product Specialist in the Cabin Product & Service Engineering department in order to have a deeper understanding of the in-flight catering as performed by KLM Royal Dutch Airlines on board of their aircrafts during the journey. The consulted expertise is used to refine and support the theoretical knowledge acquired by literatural research. The combined outcomes of the process analysis are integrated together in an as generic as possible overview of in-flight catering.

From meal preparation to trolley

The activities that underpin the onboard experience of a passenger are immensely various. It covers menu development, preparation of dishes and meals through a complicated supply chain, loading (enormous) quantities of products on an aircraft and has complex cost structures.

Except for the broad range of backstage activities and responsibilities, the in-flight catering process also encounters numerous constraints and criteria in order to provide a meal to a passenger. To mention a few:

- the function of the meal in relation to the flight patterns, i.e. which day part is covered (breakfast, mid-morning, lunch, mid-afternoon, evening meal, overnight)
- the size of the tray or bag, overall presentation and dish specification for each airline in relation to the routes being flown and aircraft being used
- the various types of passengers, and their special diets, religions, ethnic meals, and vegetarians
- the capabilities of the flight kitchen, its labour and equipment in relation to routes flown and flight centres used
- the time of the year

Naturally, the process from preparing a meal to loading the trolley at the caterer, is fully intertwined with the onboard process from trolley to passenger performed by the cabin crew in the air. The whole organisation of a single meal is interrelated with many factors, as can be seen in the next figure. With so many factors that have influence and a multitude of constraints, it is evident that the process of in-flight catering is focussing on efficiency (Jones, 2004).

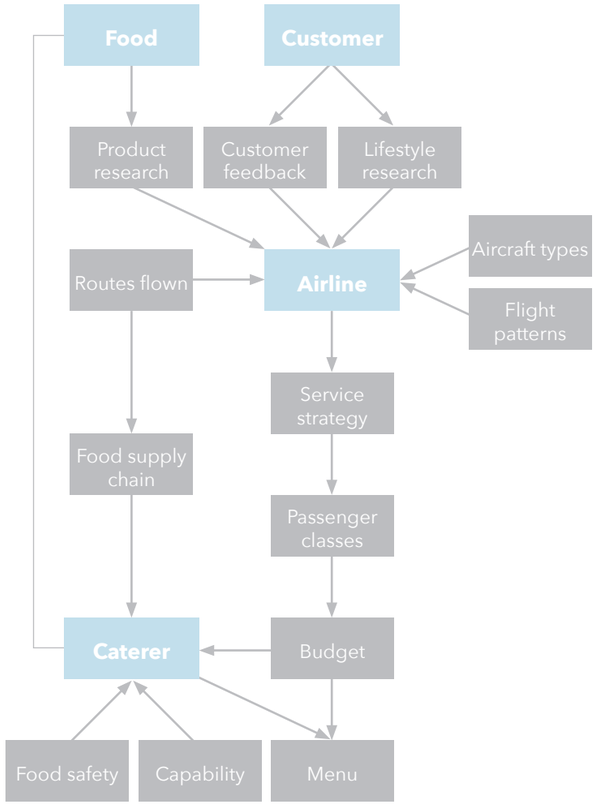


Figure 4
Elements of the in-flight catering process (Jones, 2004)

Onboard Services is a composite of many products. For now, three key products on board of the airplane are described.

Galley
The galley is a fixed monument in the aircraft. It includes equipment with functions such as heating meals, preparing trolleys and storage of the large amount of food and drinks. Each galley is tailored to the airline's chosen standardisation and mostly has an industrial, functional appearance, with little to no distinctive branding in sight. In other words, a manufacturer develops several interiors for the same type of aircraft for different client airlines. Likewise, it is possible that an airline has different galley layouts in the same type of aircraft, because of different galley manufacturers.

Figure 5
Galley of an Airbus A340-300 of Air Canada
(Wikimedia Commons, 2007)

Trolley
Service trolleys come in different sizes since there are several standardisations. Aircraft and cabin equipment manufacturers build different sizes according to the standardisation chosen by the airline. The most commonly used standard is ATLAS, which are generally 301 mm wide, 810 mm deep and 1030 mm tall. An unladen trolley weighs about 15 kilograms and could weigh up to a hundred kilograms if loaded. The trolley also exists in half size, which is half the depth (405 mm) and only opens on one side. Other trolley family standards are ACE and KSSU, which is among others, used by KLM Royal Dutch Airlines.

Tray
Conventionally, the economy class meal is composed of multiple smaller dishes and displayed altogether on one tray. The trays including items, need to fit the trolley and the folding table of the aircraft. Cutlery, napkins and typical condiments like salt, pepper and sugar in small sachets are pre-packed. In business and first class, meal service differs with more diverse choices, beverages and the option to order anytime. With this, the workload of the cabin crew working in business and first class increases, therefore the type of service is only possible for a highly limited number of passengers.

Taking a closer look at the actual content of the meal itself, the caterer prepares a wide range of food to meet all specific needs of the airline, aircraft and passenger, for example:

Breakfast
Pancakes, eggs, pastries, fruit bowls

Dinner
Chicken, beef, fish with rice or pasta, vegetables, side salad, a small bread, dessert

The main dish on the tray is served warm to the passenger. Therefore, this type of meal or component is often referred to as 'hot dish' or 'hot meal'.

Figure 6
A common economy class meal tray of Singapore Airlines

Procedure

Only hours prior to a flight, the caterer receives an exact number of passengers from the airline and thus how many meals to prepare. Special meals for passengers with an alternative diet such as medical or religious ones usually need to be ordered 24 hours in advance or during booking though. Dishes are then prepared and plated under strict hygienic rules, trays are being assembled and trolleys are filled. The kitchen is divided in hot and cold dishes, as is the meal tray. The filled carts are being chilled and once everything is ready, the trolleys are transported in trucks to the aircraft, where it is loaded during the turnaround.

During the turnaround, the previous empty, dirty trolleys are being off-loaded and the newly filled trolleys with fresh meals will be loaded in the aircraft within a short period of time. In the aircraft, the trolleys are stored in the galley (Avakian, 2019).

Once in the air, the separated hot meal compartment can simply be reheated by the cabin crew, using the convection oven in the galley. After reheating, the cabin crew simply loads the hot compartment to the plated tray during meal service. The specific tasks of assembling the tray by the cabin crew in the galley may differ per airline.

Figure 7
From top to bottom: hot meals being prepared under strict regulations; trays are assembled by a caterer's employee; a galley oven where hot meals will be rethermalised before serving (Avakian, 2019).

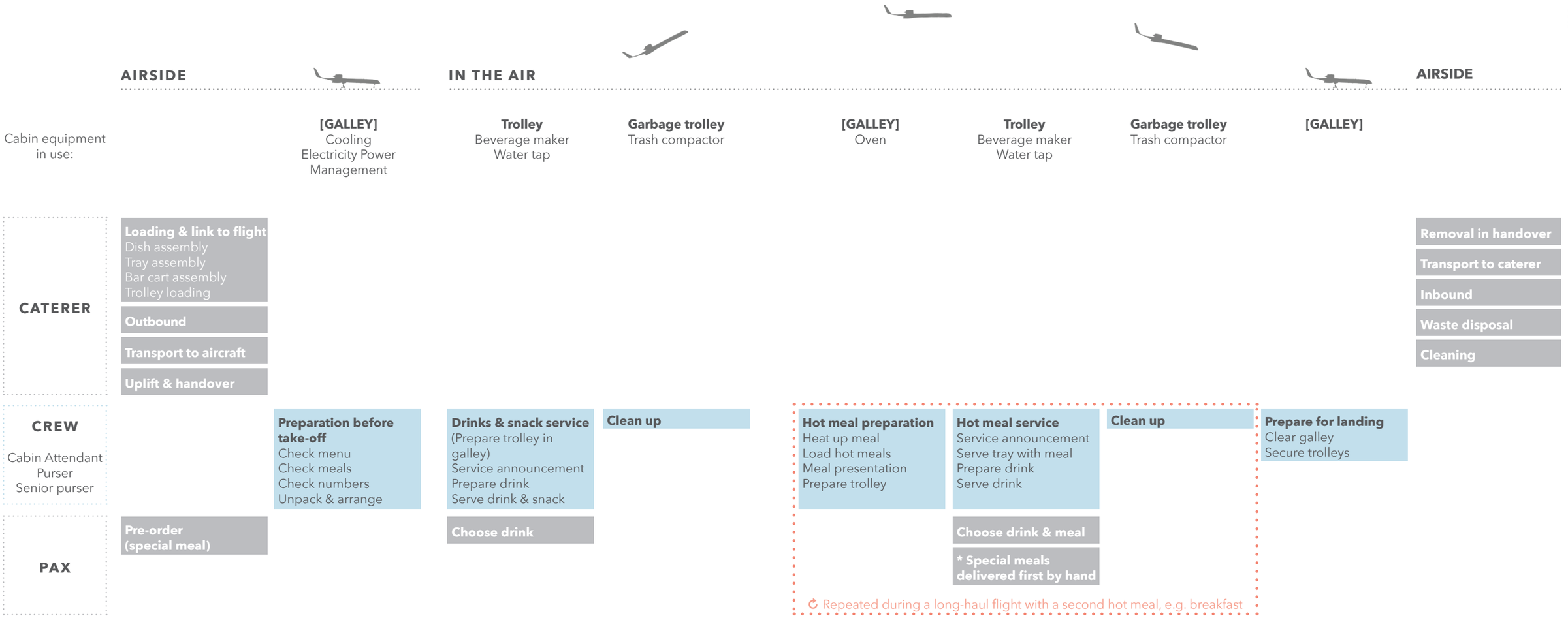


Figure #
The operational journey of an in-flight meal related to its environment and process of today. On airside, the caterer prepares the dishes, trays and trolleys per flight. This is loaded into trucks and handed over during the turnaround. Once in the air, the cabin crew prepares for service in the galley, which is equipped with beverage makers, ovens, fridges and trash compactors.

Service procedure

The conventional procedure of meal service, especially on a long-haul flight, is commonly known for its trolley and being pushed by the cabin attendant with beverages and sets of trays with hot meals. There are some slight variations in the service models. Most regularly is the principle of choosing one of the two available hot dishes and being handed over the meal tray set, passenger by passenger, row by row. This conventional routine-based service is usually included and offered twice to all economy passengers during a long-haul flight. This means that the procedure of the meal service is repeated one more time, usually not long before landing.

Other types of service

On board of most low-cost carriers, which means mostly during short-haul to medium-haul flights, meal service takes place based on a 'buy on board' principle, as food and beverages are excluded from the ticket price. This means that the step of payment is added to the service procedure. It could also happen that food and beverages can be ordered via an interface such as the IFE-screen or a personal device during the flight.

Another option allows passengers to make their meal choice prior to the flight via an interface, for example whilst checking in. The meals are either included or paid for separately and can be served likewise with the use of a trolley. However, it requires extra attention from the cabin attendant to serve these pre-orders, just like special meals.

The in-flight catering process influence and impact on cabin crew

Any product in the whole cabin environment has its influence and impact on the cabin crew working progress. While the menu changes regularly, the cabin crew needs to evaluate the service and required work that comes along with the amended menu. Therefore any changes deriving from tableware, equipment etc. needs to be evaluated too, since this has direct impact on the load and weight of the trolley and aircraft for instance, and thus impact on the cabin crew.

The onboard work method of assembling or serving a meal tray is also a logistical process. The many different trolleys that are stored in the galley are needed at different moments of meal service (e.g. a trolley loaded with breakfast, another loaded with beverages) and is therefore important for the cabin crew and the work process to be placed efficiently.

One dominant factor that has major influence on the working process of the cabin crew is the actual number of passengers. As airlines tend to carry more passengers in a plane, it means that the load of the galley increases, as the required food and beverages increases equally. This directly impacts the cabin crew: they are responsible for even more passengers on a flight and require to deliver more in the same time span. Especially in narrow galleys, this process becomes more difficult for cabin crew.

2.2 The influences of in-flight food

Why the food

Once upon a time, in-flight food was introduced to calm fears of flying. Although humanity's biggest fears of flying may be decreased by now, the in-flight meal still plays an important role in the overall flight experience. In the end, passenger satisfaction contributes to loyalty towards the airline.

There are four different ways highlighted wherein food plays a functional role during the flight. It appears that the meal service can cause certain experiences or lead to the following emotions.

1. Food as comfort

During a flight, a passenger experiences certain levels of comfort and, almost inevitably, discomfort. Depending on multiple factors such as class, cabin environment or duration of the flight, these levels may vary, but it appears that during eating and drinking, the level of any discomfort independently decreases more than for other activities. Discomfort decreases even more when a complete meal is offered (Hiemstra-van Mastrigt et al., 2015). However, food does not cause the largest drop in discomfort, as knee space has the highest correlation with comfort (Kremser et al., 2012). According to another outcome of Hiemstra-van Mastrigt et al., discomfort decreases significantly after each 15 minutes break between conditions, during which passengers could perform some physical activity by moving, for instance stretching some legs and walk around.

2. Food as distraction

Although food is not correlated as the highest with comfort, it can distract the passenger from its lack of leg room. As the study of Bouwens et al. (2017) suggests, food and drink service provides the passenger something to do and it distracts them from boredom and discomfort of lack of leg room. Under the same physical conditions, the comfort can therefore be rated significantly higher with the addition of food and drink service.

3. Food as entertainment

Besides being 'comfort' food, in-flight food can truly cause a positive emotional reaction. As stated by Yao & Vink (2019), this actually occurs when passengers are informed that the food service will start shortly, as expectations raise and is something they look forward to. Food is then considered as a form of entertainment and hence passengers want it to last longer. Eating can indeed make the experience more interesting. Pine et al. (1999) mention that in-flight food can function as a form of entertainment, like in certain theme parks.

Despite the fact that passengers want this 'entertainment' to last longer, passengers do not necessarily want to eat more. This may possibly be explained by several reasons. Passengers frequently have a low appetite that could be caused by the slower digestion or stomach discomfort by motion sickness. Another possibility is that passengers would

rather avoid the lavatory due to hygienic reasons or long queues (Yao & Vink, 2019).

4. Food as overwhelm

Conversely, in-flight food can also cause negative emotions. Although passengers expressed that they appreciate the food service, they also feel negatively overwhelmed by the abundant objects present (e.g. food tray, fold down table, personal items etc.) and multiple activities simultaneously (e.g. watching a movie, being served by flight attendant and eating a meal), resulting in a combination of positive and negative experiences (Bouwens et al., 2017). Reliant on the snapshot of the moment in time, the meal service can improve or diminish the customer experience.

Although food itself plays a determining role in the food experience, a good meal is judged as much by its surroundings where the food is served as what appears on the table (Gottdiener, 2001).

Influences on food

In fact, Meiselman (2003) shows that experiencing the same food in a different setting can offer a different experience. In the study, the importance of three factors of food quality: meal context, expectations and eating location, are evaluated with significant difference for the same food items in different settings.

According to Messner (2016), the food quality perception is strongly interrelated with an airline's service environment. If the in-flight service environment is good, passengers tend to perceive the food quality as good. Messner's research model indicates that the quality of cabin crew service is the most important variable in comparison to seat comfort and in-flight entertainment that influences the perception of food quality. Messner claims that this is logical because 'service encounters are first and foremost social encounters' (McCallum and Harrison, 1985), as the interaction with the stewardesses and stewards onboard replaces the usual interaction with dining companions in a restaurant setting.

If the value of in-flight food is assessed in its environmental context, the evaluation can potentially differ based on the seat location (Han, 2013). So while the airplane's surrounding actively influences the perceived quality of in-flight food, Ahmadpour et al. states that the first impressions of the cabin environment actually highly determines the passenger's overall experience. These first impressions are set in a timespan within 12.8 ± 4.5 minutes of a short-haul and 31 ± 19.5 minutes of long-haul flights. This means that the entrance of an airplane is highly important where passengers get their first impression. In common airplanes, these entrance doors are situated at the galley, the kitchen of the aircraft.

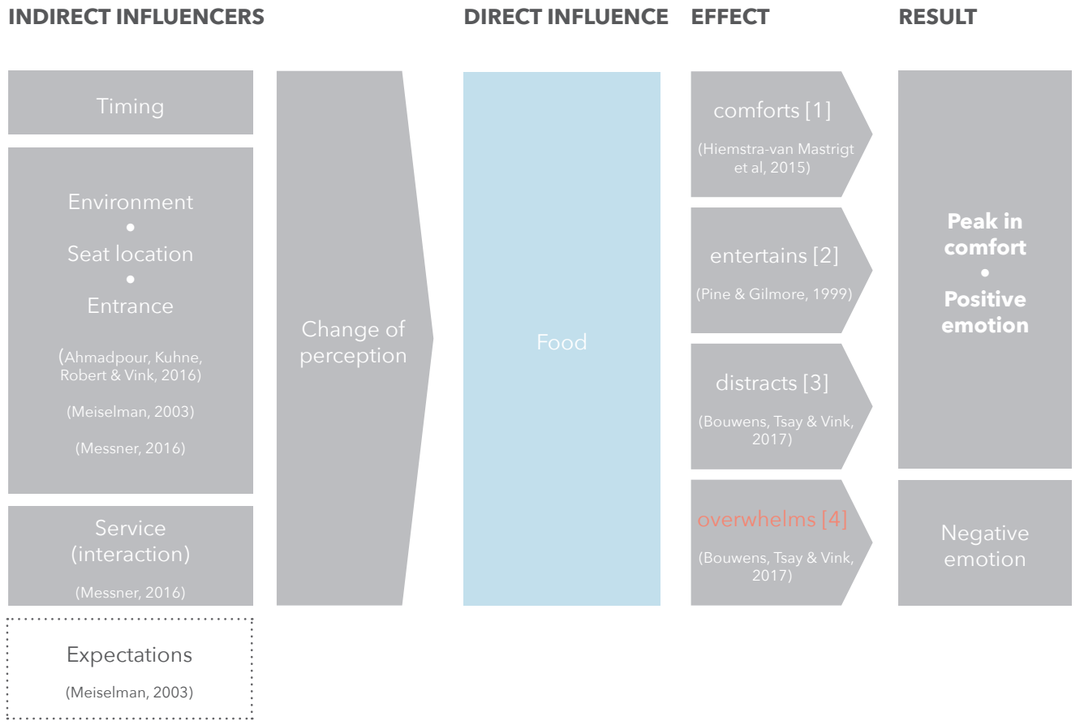


Figure 8
The role of food as influencing factor of the flight experience in a schematic overview including its perception influencing factors

The varying influences of food discussed earlier, are listed and displayed in figure 8. The schematic overview is showing the different factors and effects on the consumer in the end. The impact of the several factors are not quantified in here, but most certainly affect the food perception and emotion of the passenger, and thus the flight experience.

KEY TAKEWAYS CHAPTER 2

The process of the existing in-flight catering has been and still is highly focussed on the efficiency of its logistics and supply chain. This explains the current way of working and also leads to certain outcomes when analysing the influence of food.

- The pressure on cabin crew during the meal service is high. They have to serve more and more passengers in the same time frame while space becomes more limited. Meanwhile, the cabin crew service is actually the most important variable that influences the perception of the food. Multiple factors are proven to indirectly influence the perception of the in-flight food quality. The same food can be perceived different by the passenger because of different surroundings. Therefore the indirect factors of **timing, environment and service interaction are important contributors** to take into account in order to create an improved food experience.

- During a long-haul flight, the level of boredom and discomfort is high. Next to physical movement/activity, food has a positive influence on the passenger. **Inflight food can comfort, distract and entertain** the passenger. With this positive effect of comfort, distraction and entertainment, the passenger's comfort level and positive emotion curve is increased and boredom is reduced.

- On the contrary, passengers sometimes experience negative emotions during the in-flight food service. This is due to the reason of **overwhelm**: the several objects and activities are simultaneously present in the situation causing a feeling of being overwhelmed by the busy surroundings.

- Timing is already mentioned as an indirect factor that has influence on the food experience. More specifically is the time frame wherein the passenger gets the first impression whilst boarding. It is proven that the first 31 ± 19.5 minutes of a long-haul flight highly determines the whole flight experience. One of the first views a passenger gets within this timespan is the sight of the galley.

3 Fast forward to the future ▶▶

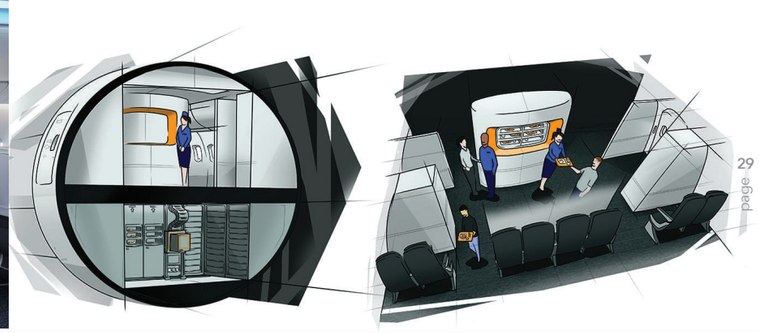
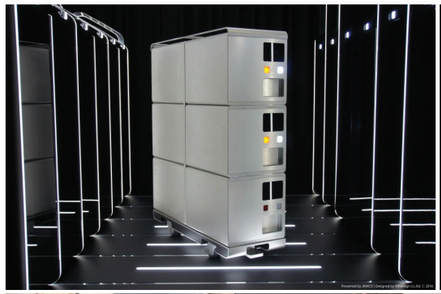
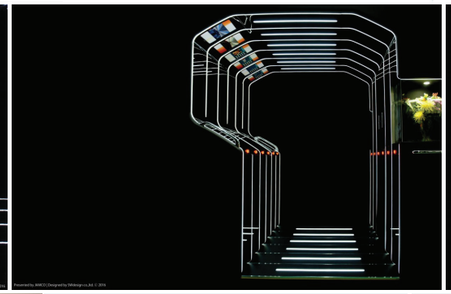
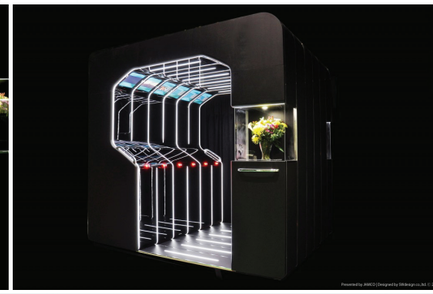
3.1 The cabin environment in 2050

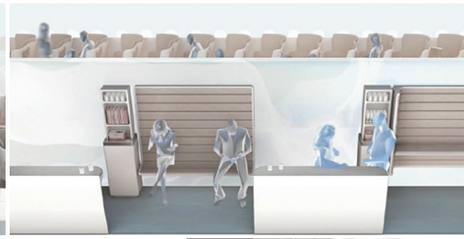
There are several concepts and case studies developed by design agencies, airlines and manufacturers wherein they envision the future context of the cabin environment. These recent developments within the cabin environment are not necessarily radical changes in the in-flight catering industry, but showcase the possible change of direction in the future air travel context.

In order to have a better understanding of this, several concepts and newly introduced but already existing interiors are analysed. Their unique selling points are clustered in a few themes that frequently occurred.

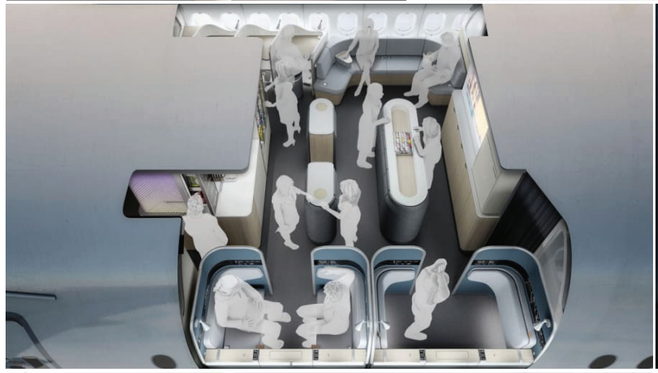
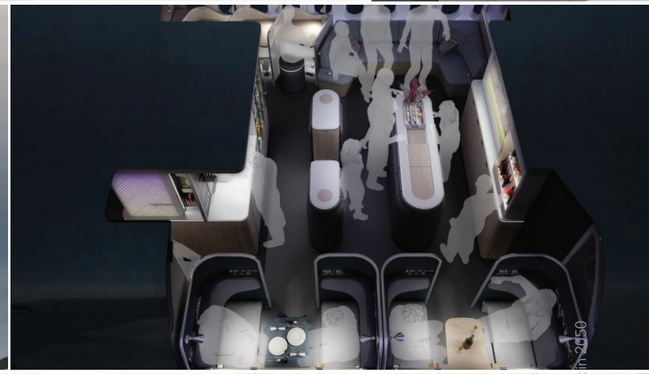
1. Digital

Digitalisation is an inevitable component in the future or perhaps could be even called the starting point. With the possibility to 'smarten' the cabin environment, equipment becomes connected. Connectivity has been an uprising curve and the number of connectivity in airplanes is expected to be tripled in 2025 already from 7.284 aircrafts in 2017 to 23.100 in 2025 (Airbus, 2018). Intelligent, connected cabins enables opportunities with possible impact on the entire OS. A digital inventory management can relieve work of flight attendants and makes it easier for them to perform tasks by faster and easier communication between human and machine with a digital interface, showing real-time information. Furthermore, it could manage expectations of passengers with the digital information.



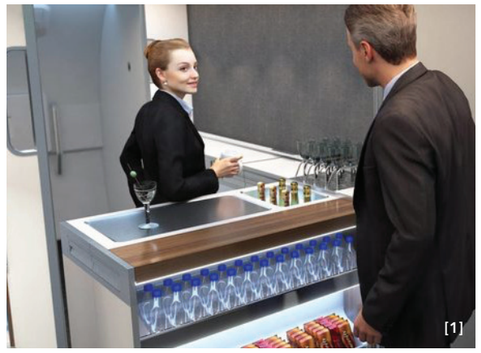

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Figure 9
[1] Modular bar with self-service shelves by Diehl Aviation
[2] Self-service concept ULTRAFLEX by AIM Altitude
[3] JetBlue's self-service snack and drink station
[4] Teague's self-service bar in concept Poppi
[5, 6] The multiple usage of ULTRAFLEX to facilitate various needs of passengers during the flight
[7] Self-service/social area using the exit by Collins Aerospace

2. Self-service

Customer service by the cabin crew is mostly seen as one of the important values of a customer-driven airline to distinct themselves from the competition. Airlines are adding self-service into the customer experience in order to deliver a smooth and seamless journey across channels and touchpoints. Self-service is not only viable on the ground as check-in kiosks at airports or do-it-self cashiers, but is also visualised in multiple cabin concepts. In the case of JetBlue, this has already become real. The airline's A321neo features a self-service snack and drink station which is designed to be more inviting and destined for passengers, instead of the classic galley design (Gavine, 2019).

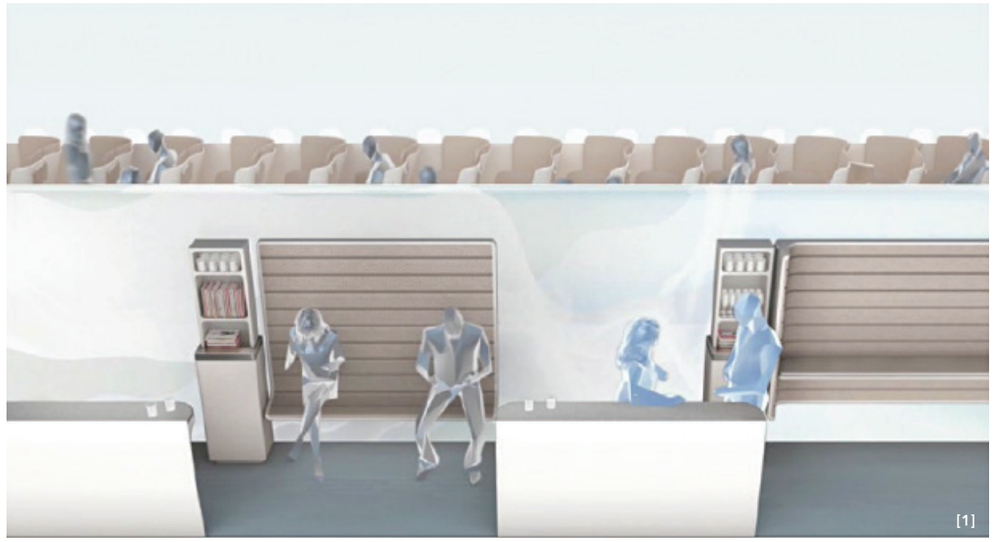

[5]


[6]

[7]

3. Flexible

Several future interiors allow flexibility to provide more options for passengers in the same area. In the ULTRAFLEX concept by AIM Altitude, there are small private booths that allow passengers to dine together. When the seats are folded, a personal space is created for passengers to do physical exercises or religious practices. Another form of flexibility (and self-service) is showcased by Collins Aerospace, where the unused space at the aircraft doorway has become extended galley space and is optimised into a self-serve social area for passengers and provides additional workspace for cabin crew.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4. Social

Another frequent theme that comes back is the social aspect. Galleys are envisioned as an accessible area where passengers can enjoy a food and drinks together. However, the space needed for this type of area is valuable and is most likely only viable if minimal or no seat reduction is the case.

Figure 10
[1] Social area concept by Zodiac Aerospace
[2,3] Social areas in the ULTRAFLEX concept
[4] ARCA galley system AIM Altitude with meal boxes instead of trays, a foldable trolley and drink station
[5] PriestmanGoode's zero waste meal tray
[6] Hi Fly replaced their single-use plastics of their in-flight meal service with products made of bamboo, which is long-lasting and reusable
[7] KLM's crcular meal tray set-up
[8] Refillable drinking bottle by PriestmanGoode made of cork and compostable bioplastic


[4]


[5]

[6]

[7]


[8]

5. Sustainability

In a strict industry as the airline's with countless rules and regulations, change is complex to manage, despite the urgency in the field of sustainability. To target this, it is crucial to have a holistic view.

The practice of ARCA galley system shows how an inclusive design of the galley, integrated with digital customisation, touches upon the sustainability challenge. The concept points out the fact that current meal trays take unused space due to the separated hot meal and drinks. Their solution is to replace trays with customised meal packs, which become smaller and stackable. And with customisation, passengers receive the food of their choice, likely resulting in a reduction of food waste.

KLM Royal Dutch Airlines is carrying out a test with a circular meal tray set-up. The closed loop is reusing materials on flights between Vancouver and Amsterdam and allows the reuse of plastics conforming the regulations of hygiene and safety.

3.2 Trends & developments analysis

The future passenger

Air transport is growing, more people are travelling and more frequently as a result of globalisation (IATA, 2011). The major division is (still) between leisure passengers and business passengers. While business travellers still value their time above all else and are therefore willing to pay a premium price for extra convenience or ease, leisure travellers seek for **experience enhancements** that fit their personal needs. Next to price, the flight experience is of major importance, as many view the journey as part of the whole leisure experience. For both passengers, the International Air Travel Association envisions a faster (when desired), safer and more seamless way of air travel for the future, with more international and cross-cultural travel as a consequence of globalisation. This makes the passenger becoming more and more a globe-trotter (IATA, 2011).

↘ DESTEP-analysis

To have a clear view on current developments in multiple areas and not to be limited to the field of air travel, a DESTEP overview is made to predict possibilities and foresee opportunities on meta, macro and micro level and all fields: demographics, economy, social, technology, ecology and political. Three relevant outcomes are further elaborated and presented in this chapter.

► see appendix B

Convenience is the new food

Food is changing, as the consumer demands for more transparency (Forbes, 2019). Food brands are becoming more local, organic and fresh and its ingredients list becomes shorter and more natural (KPMG, 2016). While convenience and experience is of greater value, food is expected to be both quick and healthy. It does not stop at healthy trends as nutritious snacking in the consumer's diet. Next to more variety and ethnic cuisines, the way of eating develops too. As France's most feared food critic, François Simon of Le Figaro, once stated: *"Today people consider the table a place where they want to feel at ease."*

The rapid adoption of connectivity via mobile devices changes the food industry into a **customized, technology-enabled** experience. Not only on the ground catering, but also in the air, connectivity becomes a standard. As previously mentioned, the number of aircrafts with digital connectivity is skyrocketing and expected to be tripled in a few years. Not only does the cabin environment become **connected and smarter**, data of the flight can be analysed and predictions can be made in order to improve the available assortment on board and possibly reduce waste. As technology enables more and more convenience, it is now possible for the in-flight catering industry to customise more meals and enable pre-ordering (Wired, 2018).

From a consumer perspective, the wish for customizing meals or convenience is not newly stated after the digital development of the world. In a study of 2001, they found that most customers want to have their inflight meal delivered at their own pace, to, for instance, have more time to rest or work (Martin, 2001).

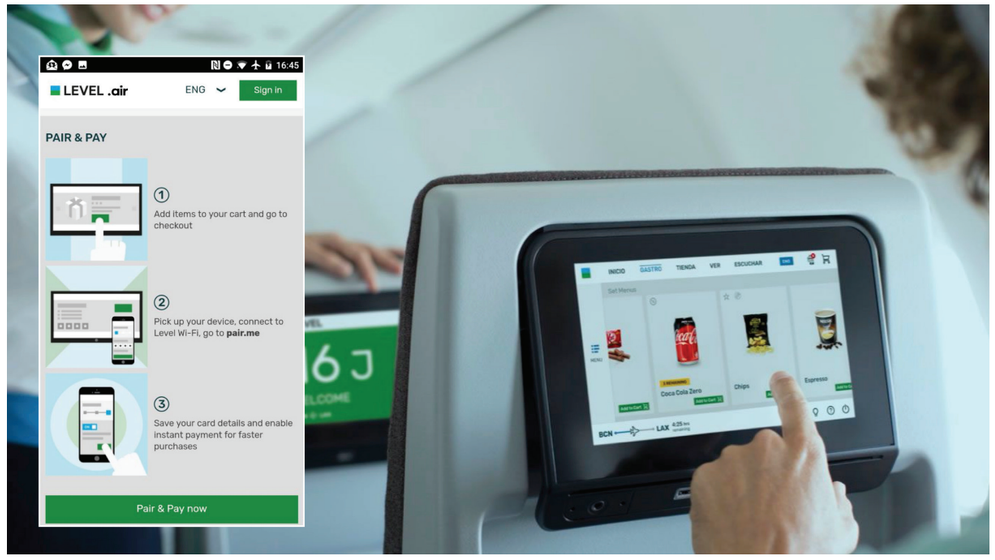


Figure 11
One example of a customized, technology-enabled experience is the service of LEVEL airline. Passengers use the IFE-screen to place an order and pair up with their personal device for payment (Airlinetrends, 2018).

Mobility rises and changes

Air travel has risen broadly in line with world trade, which made it possible for low-cost carriers to enter the market too. These budget airlines have driven up the volume of air travel passengers massively. However, while the volume of air travel is increasing, infrastructure is having its challenges to grow congruently. The construction of new airports and the addition of new capacity to existing airports still is a highly political process that involves extensive government permitting (IATA, 2011). Congested airports where slot capacity is reached, force limitations upon airline and customer to cope with the growing demand for air travel and its consequences.

As an airline with the wish to grow, but not being allowed to fly more planes, one alternative solution is to fit in more passengers on a flight. This comes with **implications for cabin interior**, catering and service delivered by the cabin crew, as they are only allowed to oversee a maximum number of passengers per cabin crew member.

On the ground, automotive products are changing and becoming more connected as well. These days, an average modern high-end car has 100 million lines of code, 15 times more than Boeing 787 avionics (McKinsey, 2019). This is deriving clearly from the four technology-driven megatrends in the automotive industry: Autonomous driving, Connectivity,

Figure 12
Self-driving robot in a fully autonomous restaurant (Reuters, 2020)

Electrification and Shared mobility. The study of Milakis identified plausible future development paths of automated vehicles in the Netherlands (Milakis et al., 2017). According to the scenario analysis, it is most likely that fully automated vehicles have entered the market by 2050. The impact and potential implications for traffic, travel behaviour and transport planning is variable among the scenarios though. According to McKinsey (2019), robotaxis will become a cheaper mobility option than private vehicles in urban environments. Nevertheless, the four megatrends influence customer's mobility habits. The demand for individualized products such as pay-per-use mobility and demand for sustainable mobility will rapidly increase, while the existence of connected or autonomous vehicles becomes merely normal for us in 2050.

In addition to that, autonomous vehicles in the shape of small delivery robots are already expanding in the food delivery industry (Forbes, 2019). Except for delivery, autonomous robots are also being introduced in restaurants, where consumers can take the order from a self-driving cart in a fully autonomous restaurants, starting with relatively simple coffee orders (Nu.nl, 2020).

Sustainability is key

Corresponding to the ageing world population, passengers will be older on average. While the average age is higher, the passenger is not necessarily less mobile. The millennial generation still is the largest consumer group (IATA, 2011) and is also the consumer who is most willing to spend more on sustainability (Nielsen, 2015).

As sustainable awareness is rising, environmental concerns put pressure on the air travel industry due to its large carbon footprint. On a consumer level, consumption is developing into **ethical consumerism** (IATA, 2011). This demands for corresponding products such as eco-compensation for conscious travellers, namely millennials, or the rising demand for local food products (Business Insider, 2017). This has also led to several changes in the cabin products or service. On average, a passenger produces 1.43 kilogram of waste per flight, which goes to landfill. 80% of a flight's waste derives from the cabin, consisting of single-use plastics as cutlery and cups. To address this plastic waste, single-use plastic-free flights are introduced (Future Travel Experience, 2019).

Except for plastic waste, on a long-haul flight, 9% of its total waste is **untouched food waste** (Li, 2003). According to the figures of Fiji Airways, almost a third of their Australian passengers skip in-flight meals in favour of some extra sleep. As a result, it appears that 38% of the food is being discarded. Although it can be assumed that the timing of in-flight catering during the flight is unfortunate for Australian passengers, nevertheless, the food must be loaded and be available for passengers, with the risk of not being consumed. But, with the use of data and increased connectivity on and above the ground, airlines can offer customised meals for those who pre-order and predict the orders of those who did not order in advance, changing the passenger service.

Opportunities in corresponding trends and developments

The outcomes of the trends and developments analysis are set side by side to elicit similarities and differences. Within this overview, **see figure #**, there are multiple links between factors that have actually influenced each other and made the trends and developments as they are now.

As a consequence of individualisation, consumers have become more experience focussed. Also the rise of the millennials, who are more aware of their consumption, has influenced consumer trends. This combines ethical consumerism with sustainability and the aim to reduce, reuse and recycle among consumers.

From another perspective, technology enables more customisation and connectivity, allowing consumers to adjust their product experiences and to fulfill their (ethical) needs.

Meanwhile, the airline industry is developing and entering a fully digitalized world wherein the use of big data can predict more accurately the needs and wishes of passengers. While the airport infrastructure - and thus the airline - is limited in capacity and growth, the number of passengers is growing and growing. This means that a solution is needed in order to cope with this growth in passengers and to keep customers satisfied within the limited possibilities in terms of capacity.

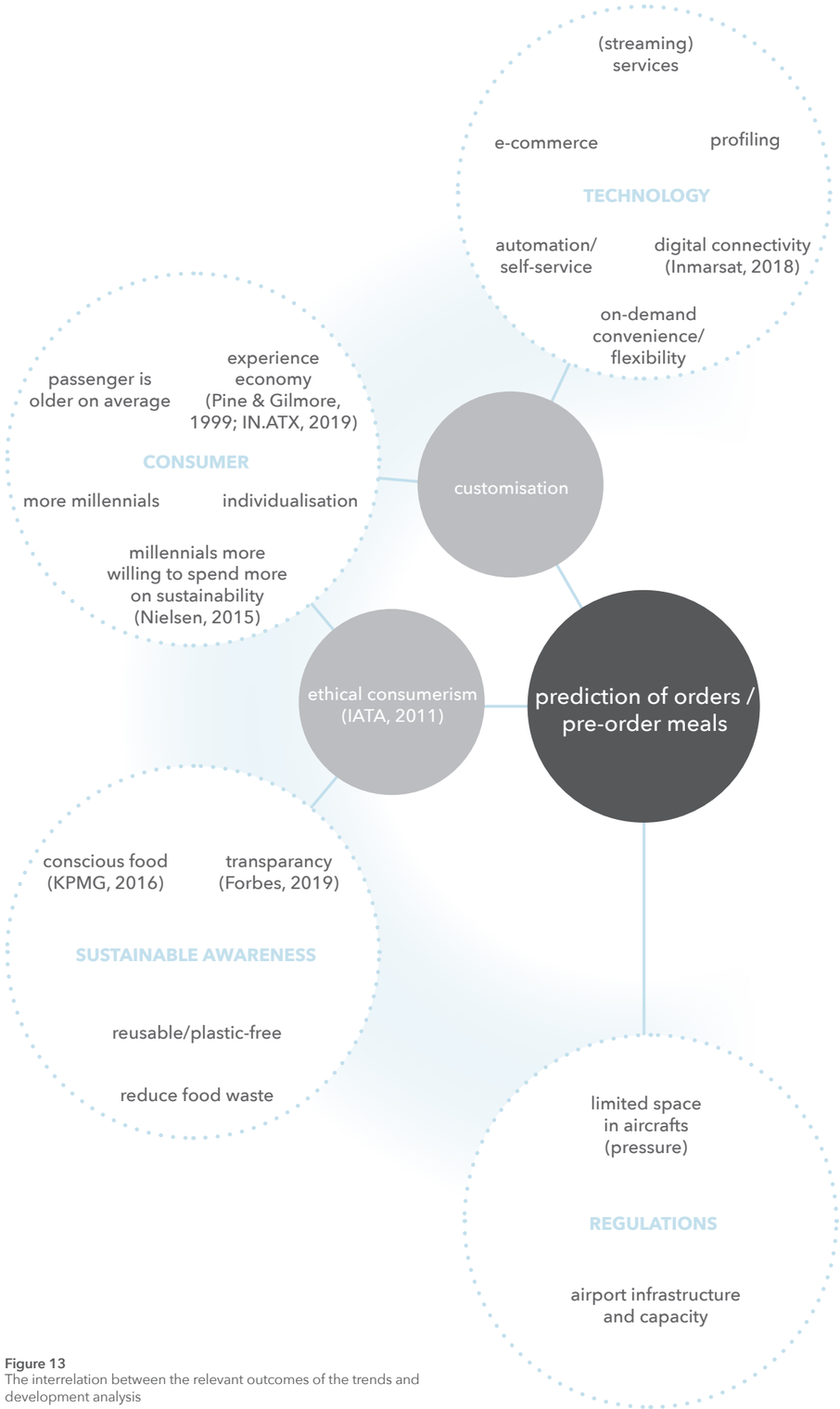


Figure 13
The interrelation between the relevant outcomes of the trends and development analysis

3.3 Crew perspective on 2050

To have a better understanding of the cabin crew and their possible concerns regarding in-flight dining, they are consulted by a co-creation session. In this way, past experiences based on the current cabin environment are pushed to the background and is the open future of in-flight dining emphasized instead. This session is set up with the goal to gather input from various experts, to collect and cluster their perspectives into guidelines for the conceptual phase.

↘ Co-creation

The very literal meaning of co-creation is: together (co-) make or produce something (new) to exist (Koning, 2017). Now, in this session, participants contribute by offering their expertise and knowledge as a resource. These experts invited to co-create were two representatives from Safran Cabin Design and six representatives from KLM Inflight Services. This chapter only shows a broad overview of the session and its results. In the appendix, a more detailed overview of the co-creation session and elaboration on the process can be found.

► see appendix C

The co-creation highlighted many ideas on how to approach the main challenge: 'How do we feed an entire aircraft in 2050?' These ideas and discussions that were raised along gave valuable insights into the thoughts and concerns coming from crew. The insights are clustered in broadly four key perspectives:

Operational
The catering operation is positioned midst the continuous battlefield between the business and consumer aspect. Galley space for a better customer experience and service is always weighed up against seat space for profit.

Crew experience
No flight is the same. Customers make the job diverse. This diversity and interaction between

Figure 14
Experts of Safran Cabin Design and KLM Inflight Services brainstorming and discussing ideas for the future meal service

crew and passenger are the most enjoyed during their (cabin crew) work.

Flexibility
Passengers like being in control and being able to choose. It is about what they are going to eat and drink as a matter of fact. Giving them control over the situation would expectedly increase customer satisfaction.

Customisation
Cultural differences influence the needs of passengers, making cultural customisation relevant to fulfill these different needs. In current flights, meal menus are varying in demographical or cultural dish types. However, differences are shifting because of globalisation; people travel more around the globe and are more connected than ever. Future differences in customer needs are not longer demographically, nor culturally bound. This means that the food demand is changing too.

This input of the experts is used in the next chapter of the synthesis to create appropriate design guidelines.

KEY TAKEAWAYS CHAPTER 3

A wide range of insights is gathered through the case study into existing concepts, trends and developments analysis and co-creation with experts. These insights combined, elicit several similarities that prove to be relevant outcomes for the next phase:

- The future cabin environment is likely to become fully **digitalized** by the rising connectivity in the aircraft. This enables opportunities in the customer journey that can change the future of in-flight dining.

- Consumers tend to be more in control of their 'product use/customer experience'. Transparency in products is therefore essential, as consumers become more aware of their (ethical) consumption. They demand for **personalisation** to adapt to their needs.

- Many aspects of **sustainability** are addressed in the OS by reducing, reusing or recycling materials. One of the frequent topics is (food) waste. A lot of untouched food is wasted because of inconvenient timing, preference or personal appetite. This actually points out that the existing fixed meal service is in conflict with certain passenger needs, resulting in waste. Furthermore, the way the meal is presented nowadays does not only result in a lot of waste, but also uses the space inefficiently because of reserved space for the hot meal component and drinks.

- **Interaction** is an important aspect of in-flight catering. During the meal service, the two roles of the passenger and the cabin attendant are key in the in-flight dining experience. It is important that the designed in-flight catering concept facilitates human interaction any how in the future of 2050, because it does not only influence the in-flight food perception for the passenger, but is also an important enjoyable aspect of the work of cabin crew.

4 Synthesis

4.1 From insights to vision

In this chapter, the outcomes based on literature reviews, trends, developments and context analysis are combined and translated into a vision which is framing the future context of 2050. To do so, the Vision in Product Design (ViP) methodology by Hekkert and Van Dijk (2011) is partially used. Although the original method results in a future *interaction* statement to facilitate the design project, the method is now primarily used to compile a future vision statement at first, and then completed with an interaction statement as an additional tool to help expressing the desired design goal.

↘ Vision in Product Design (ViP)

This design method consists of two parts: a preparation phase and a design phase. In the preparation phase, the following three aspects will be deconstructed in specific order: past product, past interaction and past context. By deconstruction step by step, the designer gains a better understanding of the link between the design decisions in the existing products and the former context.

In the second part of the ViP method, the future context is shaped by defining the relevant factors that may affect the human-product interaction, based on principles, trends and developments. These factors are clustered and form a dimension that indicates future directions and a possible future situation or scenario. Once this storyline is set, a statement is constructed that addresses the future desired interaction.

The full execution of this design method is elaborated in the appendix. The result is a vision statement and is elaborated in the next paragraph.

► see appendix D

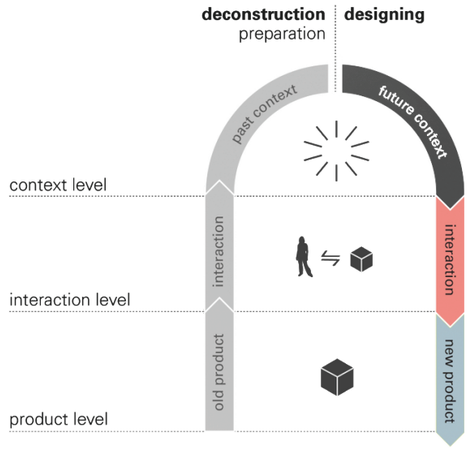


Figure 15
The phases of the ViP-method visualised in a diagram by Hekkert & Van Dijk (2011)

Past scenario (deconstruction phase)

As long as aircrafts are built, the industry has been efficiency-focussed. Also inside the aircraft, cabin products and equipment have not changed much, whilst being subject to process and engineering. It has become fundamentally restricted by a system that has barely changed since the 1960's.

During a long-haul flight, the process of serving passengers has evolved into a completely pre-arranged routine due to the continuous focus on efficiency. The meal service in economy class is a fixed schedule with little to no room to adapt to the different needs of passengers. As a result, passengers do not finish their meal or do not eat at all, because they have no appetite, dislike the quality or simply miss their meal, while meal service plays a crucial role in the overall flight experience. Additionally, this results in a considerable amount of food waste.

Future scenario

In a fully digitalised future, it is most likely that we become fully empowered by its smart possibilities. As aircraft connectivity rises, not only the cabin equipment becomes connected and smarter, data of the flight and meal service can be analysed and predictions can be made in order to improve processes, or for instance the availability and variety in the assortment on board.

From a consumer's perspective, one important digital empowerment is control, or at least feeling a sense of control. With digitalised tools and services, consumers have control and **flexibility** when to use, access, adjust, etc. a product. This flexibility is core in future consumerism. Having the ability to customise the product, consumers take a more active role by creating their own ideal user experience which fits their personal needs.

Although digital smartness unlocks new ways in doing things, such as payment for instance, **human interaction** is still key in and around cabin service. The contact moment between passenger and cabin crew during the flight is an important touchpoint, since it contributes to both passenger and crew experience. Therefore, human interaction should not be completely replaced. Nevertheless, the approach of the customer service may change because of the digital empowerment of the passenger.

VISION STATEMENT

The future is custom-made.

In the Flying-V, passengers are served custom-picked meals which can be provided at flexible times for an improved food and flight experience, in a smart and sustainable way that supports human interaction.

During the flight, passengers can feel at ease, as if they are having dinner at a friend's place, where they can find their way to the kitchen on their own initiative.

With this vision statement, a future context and design direction for this project are set. This future context is further elaborated below with a scenario sketch of air travelling in 2050. The sketch is based on a few clusters of takeaways that derive from the conducted research.

In 2050, the customer journey is smooth and seamless from booking to boarding because of continuous digital connectivity and real-time optimisation of the process and operation by the airport and airline. By 2050, the use of autonomous taxis have risen as a common mode of transport and is especially used for transportation to and from airports. Passengers can easily arrange this robotaxi when booking their ticket and drives autonomously to the airport. Once arrived, the passenger receives all necessary information, notifications automatically on their personal device for a smooth and personalised journey through the airport.

Algorithms
Customisation of meals is complex, perhaps even difficult to achieve from an airline caterer's perspective, as it suggests personalisation of each product to fulfill the many and various passenger needs. In the perspective of the passenger, it could mean higher satisfaction when the meal is adjusted to the personal needs.

It requires the necessary operational organisation in order to offer the right customisation options without creating negative consequences. A possible undesired scenario could be for example the unavailability of certain offers on board. Clever use of algorithms in AI can predict demand to diminish the chances of such scenarios. More specifically, airlines are already analyzing their data in order to predict the demand for food and beverages. With this, aircrafts can be loaded more efficient, passengers are offered the right choice and less waste is produced.

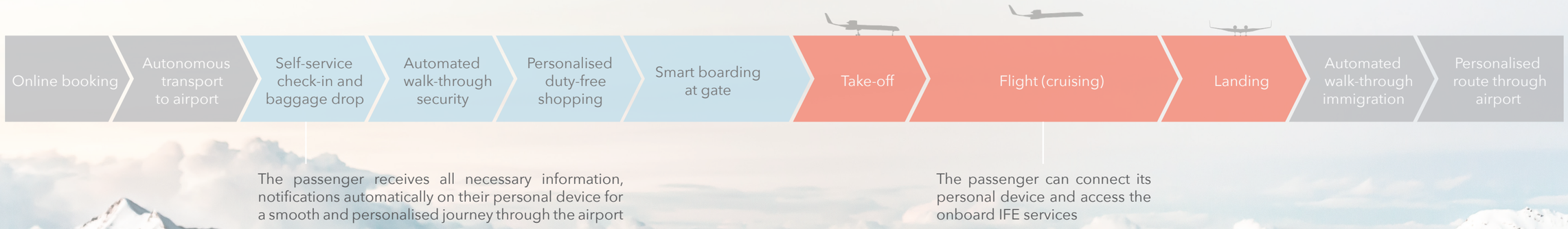


Figure 16
The possible digitalised customer journey of a passenger in 2050 from the purchase of a flight ticket to arrival at the destination based on trends and developments.

A flexible future flight does not only benefit the passenger experience, the in-flight food service can also reduce its food waste since the passenger can now fulfill its nutritional needs corresponding to the appetite and takes away the event of rejecting a meal.

DESIGN GOAL

Design an aircraft interior system for serving custom-picked meals which can be provided at flexible times to passengers for an easy food and flight experience in a smart and sustainable way.

The future vision statement with the formulated design goal remains leading in the entire project.

4.2 From vision to design guidelines

The formulated vision and future design goal are translated into a set of design guidelines which form the backbone of the conceptualisation.

First, in order for the designed concept to be feasible and implementable, it should fit the following self-evident, general requirements that emerged throughout the project and from the domain.

General domain requirements

- The equipment of the meal service must withstand the sterilisation and washing process using chemicals between flights.
- A maximum of 60 passengers is allowed for one cabin attendant to oversee on board of the Flying-V in comparible working conditions of the current.
- The 'cross-aisle' at the aircraft doors must be accessible at all times for emergencies.
- The concept and equipment of the meal service must be turbulence proof.
- The concept must fit within the available physical space of the Flying-V.
- The concept must fit within the ecosystem of suppliers, caterers and airport infrastructure/governance.
- The meal service must be compatible with outstations at the destination of the Flying-V.
- The concept must allow orders and service of special meals for passengers with special diets.

Assumptive guidelines

These additional factors are not considered as requirements since they may be strongly dependent on other context variables which are still undefined or underdeveloped. Therefore, they are drafted as corresponding assumptions and serve as additional guidelines to define the context.

- The conceptual seat configuration in the Flying-V replaces the existing division of classes and separation of its services. In other words, the concept is suitable for serving all 314 passengers on board.
- The design of the staggered seats, group seats and chaise longues are developed in such a state that dining is supported with the necessary space.
- The content of each meal in terms of volume should be equal to the current meal size.
- The required equipment and its quantity is based on the Boeing 777-200ER aircraft with a capacity of 320 passengers.
- Digital technology is compatible with the cabin equipment, enabling a smart cabin environment for both crew and passenger.
- The aircraft wings are symmetrical in its cabin interior design.

Moreover, the to be developed concepts need to be in the design direction and fit the context as described in the future vision, which emerged from the ViP-method. This design vision-specific context is framed by a set of wishes: important values that are ought to be included. The values are based on the gathered insights throughout the project.

This framework consists of three main values that are considered to be the starting point of the concept creating phase. Each aspect is comprised of more detailed values, that are relevant for the concept. Not only does this set of values serve as a starting point, the concepts can be evaluated and measured by assessing each value with a score in order to compare and select a concept.

1. CUSTOMER EXPERIENCE

Level of time convenience
The meal service gives the passenger sufficient flexibility and control to choose a preferred moment for having a meal on board

Level of food customisation
The passenger could make various choices to adjust the food experience to personal preference and appetite

User friendliness
The workload to obtain a meal should be performed with ease and with as less effort as possible for the passenger

Ergonomic advantage
The meal system stimulates the passenger's perception of the food (by either comfort, distraction, entertainment,) giving the passenger a positive emotion

Service
The cabin crew is supported in their interaction with the passenger to provide an optimized service

2. SUSTAINABLE/CONSCIOUS

Reduction of food waste
Probability of food waste in the meal service is reduced to a minimum

Disposables
The use of disposables is minimized (by reduction of these items or replacing them with reusable equipment)

Space footprint
The required space that is designated for meal service is as small as possible in order to obtain high efficiency in use of space and smaller footprint

3. AIRLINE OPERATION

Ecosystem fit
The system should fit within the operational environment of the meal preparations and turnaround: loading and linking, transport and cleaning

Cabin crew workload
The workload of the cabin crew is lower, if not, at least equal to the current situation and must fit within the routine of other processes to be performable in order to maintain an optimized customer service

Efficiency
The way of working should be smooth, intuitive and minimizing work pressure and customer dissatisfaction with an effective and efficient meal system

Prioritizing

Although the framework is a set of values as a whole, some components are slightly more relevant. The following values are considered to be vital in the scope of human-centered design and a possible showstopper if not met, and thus prioritized:
Service, User friendliness, Cabin crew friendliness and Efficiency.

The list is also translated into a rubric with corresponding scores to evaluate concepts. The weight of the four prioritised values is doubled in the evaluation.

► see appendix E

Product qualities

Except for the goal of serving custom-picked meals provided at flexible times, the interaction in the product context should elevate the passenger experience. As mentioned in the vision statement, the desired interaction is formulated as following: *During the flight, passengers can feel at ease, as if they are having dinner at a friend's place, where they can find their way to the kitchen on their own initiative.*

In other words, during the event of meal service, passengers should feel comfortable and welcomed as a guest, but its environment should empower the passenger to be helpful as well, by taking initiative themselves and relieve the host - the cabin crew - a little. The self-initiated interaction, which does not necessarily concern a human interaction, should therefore be characterized with 'comfortable', 'accessible' and 'delightful', as a dinner should be.

To design for this, the following product qualities are described and used as a benchmark for the product interaction.

Product qualities for 'comfortable'
natural
recognisable

Product qualities for 'accessible'
light
calm

Product qualities for 'delightful'
remarkable
balanced

KEY TAKEAWAYS CHAPTER 4

The results from the research are integrated into vision statement of the future travel context.

The future is custom-made.

In the Flying-V, passengers are served custom-picked meals which can be provided at flexible times for an improved food and flight experience, in a smart and sustainable way that supports human interaction.

During the flight, passengers can feel at ease, as if they are having dinner at a friend's place, where they can find their way to the kitchen on their own initiative.

In this vision, a few components are key:

- The consumer is empowered with digital solutions and becomes more independent. This requires a more individual approach of the consumer and offers in the same time a smarter way of service with a fully digital environment.

- On the other hand, a fully digitalised future does not mean that the human interaction is gone or replaced. In fact, service of the cabin crew is still key for the passenger's perception of the flight quality and elevates the experience of both parties.

- The demand for individual experiences is also a demand for flexibility, since passengers wish to adjust the products to their needs.

The formulated design goal is translated into a set of requirements and a framework of guidelines. They describe the context wherein the concept should fit and serve as a basis in the development process. Within this framework, four values are prioritized: *Service, User friendliness, Cabin crew friendliness and Efficiency.*

In order to achieve the desired interaction in the design, a few product qualities are proposed. The design should be *comfortable, accessible and delightful* in its usage.

5 Designing the Onboard Services

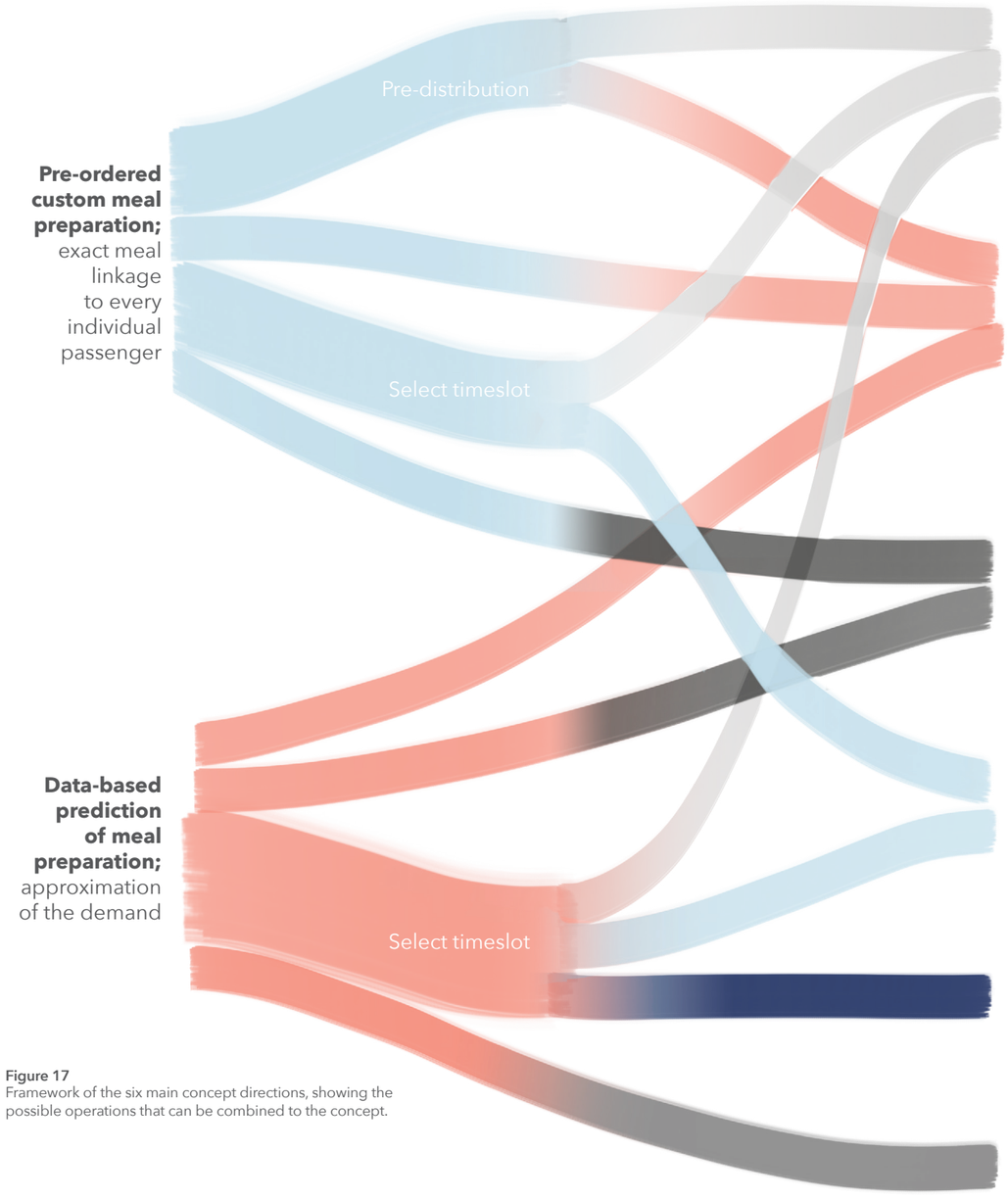
5.1 Ideation

Dining on board of an economy class flight is, broadly said, the only 'restaurant' in the world where you cannot decide for yourself what you eat and when you eat. As described in the future vision, passengers of 2050 demand for more flexibility in terms of choice and time, which is not more than common in restaurants on the ground. In the ideation phase, the thought of being free to choose where and when you eat, similar to dining in a restaurant on the ground, is kept in mind whilst brainstorming about dining in the sky.

The questions to explore in the ideation are:
- How to offer ('sell') food anytime
- How to customise a meal
- How to serve a customised meal (or not)

Eventually, the ideas are clustered into the following main concept directions:
1. Cabin crew service at your seat
2. Anytime self-service galleys
3. Takeaway galleys
4. Canteen shops
5. Buffet
6. Vendor service

These concept directions are congregated by theme, based on the interaction level between passenger and cabin attendant and are combined with different 'types' of operation. Of course within each direction, there are plenty of variations possible. This framework of the overall combinations is therefore used as an overview of the different concept directions and serves as a starting point to converge in ideas.

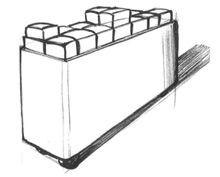


Direction 1: Cabin crew service at your seat

Pre-ordered complete meal served at your seat

Pre-ordered complete meal served during timeslot

Data-based meal offer served at your seat during timeslot

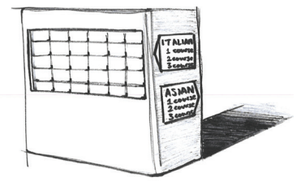


Direction 2: Anytime self-service galleys

Pre-ordered meal heated by yourself

Pre-ordered meal at self-collect machine

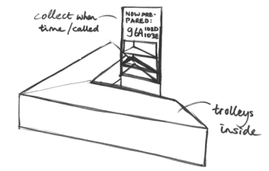
Data-based meal offer at self-collect machine



Direction 3: Takeaway galleys

Pre-ordered meal at takeaway galley

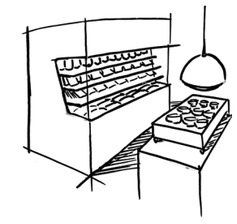
On-demand meal service at takeaway galley



Direction 4: Canteen shops

Grab a pre-ordered meal during timeslot

Grab a meal in canteen during timeslot



Direction 5: Buffet

Self-service buffet during timeslot

Direction 6: Vendor service

Multiple service rounds at seat

Figure 17
Framework of the six main concept directions, showing the possible operations that can be combined to the concept.

With the use of the design guidelines from chapter 4, the viability of each service concept will be measured.

An extended overview of the six concept directions with additional details can be found in the appendix.

► see appendix F

Customisation becoming a restriction

The customisation of one's dining experience could allow a higher satisfaction among passengers. Although extra options offer passengers more room to customise freely, sometimes options become a restriction. Increasing the number of decision-making moments can slow down processes. It creates one extra step after another in the process and thus has impact on the efficiency. Giving people many options like a buffet, can cause lines of people waiting.

Moving the decision forward to the booking for instance, may also rather be restricting for passengers. Any decision made prior to the flight, for example, having chosen a specific time slot and type of dish could be undesirable if something has changed in the meantime. For instance, the passenger may eat spontaneously before the flight at the airport, to kill some time whilst waiting or simply because of being hungry already. Pre-made choices may reduce the flexibility of the passenger and mismatch the real-time needs during the flight.

Flexibility on the other hand, has a major impact on the operations of the cabin crew. It could either mean a reduction of interaction between passenger and crew if the flexibility is offered by self-service. Or, it could mean an incremental or continous workload if passengers can demand for meal service at any moment. Both plausibel effects on interaction and workload are unwanted, since they are important values to measure service and cabin crew friendliness. Therefore, the balance between the offered flexibility, customisation and the cabin crew friendliness, which is a prioritized criterium, is of major importance to create a viable meal service concept.

People traffic

The concept of self-collecting meals at one point in the aircraft would offer passengers a relieving moment of physical activity that could increase the passenger comfort. Nevertheless, the space within the aircraft is limited as we all know. It would mean that the meal collection must be spread out in order to prevent passengers from standing in line for their meal. If the meal collection is not regulated with routes to and from the seat and time schedules, this flexible 'anytime' meal collection could cause congestion. A smart scheduling system can take orders from passengers, calculate the preparation time for crew and notify passengers when the meal is ready, so passengers can come by one by one.

However, from a passenger perspective, this may result in a much longer wait because it may be busy at the self-collection point. Also, if all passengers have the complete freedom to order, collect and eat at different moments, getting in and out of a seat may be even more challenging, because the system may calculate the best schedule to collect a meal, but it cannot command passengers at the window seat to select the first time slot, then passengers in the middle seat to eat and then aisle seat passengers as the last ones.

Converging conclusion

With the use of the guidelines framework as a rubric tool, the viability of each service concept is evaluated and measured with the weighted criteria. The prioritised values weigh double in the evaluation.

► see appendix G

With a final range between a 2,6 and 3,8 out of 5, the outcomes lie close. The second highest rating of 3,6 is given to **concept direction 3**. Self-service offers people the flexibility and freedom to act upon their own personal needs. Obviously in conditions alike the aircraft cabin environment, this freedom for over 300 passengers will require the needed coordination to prevent undesired, busy situations as it becomes easily chaotic in such a small space. Self-collection of meals could therefore be the right balance of self-service from passengers and the service of the cabin crew. It is a relatively efficient method if meal orders are scheduled accurately and passengers collect their meal according to that schedule. However, chances are assumed to be low that that happens perfectly. This scheduling system is therefore even more crucial for any service concept that allows passengers to be in control of their meal service timing. The cabin crew needs to be able to operate efficiently according to this schedule so passengers can have a smooth dining experience.

It is **concept direction 6**, the frequent service of cabin crew with multiple vendor rounds, that scores the highest (3,8) for Customer Experience. This service method does not take any effort from passengers and has potential to benefit the ecosystem as a whole because of the fundamental impact that it has.

This outcome of the evaluation and rubric tool generates a final perspective on what can be a viable meal service concept.

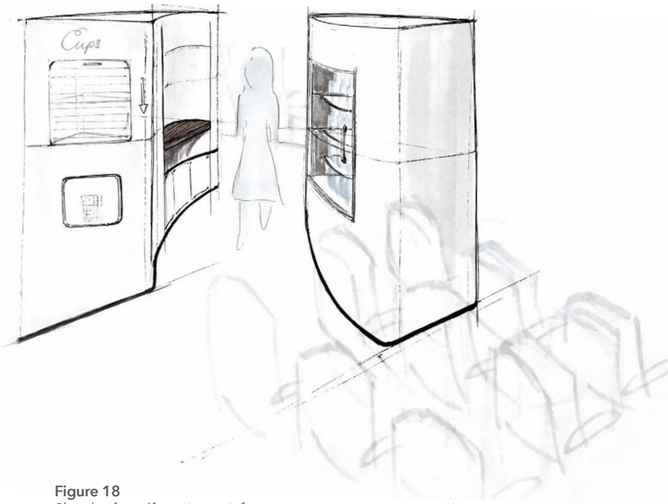


Figure 18
Sketch of a self-service unit for passengers as a monument in a possible area of the aircraft: at the centre between the two wings of the Flying-V.

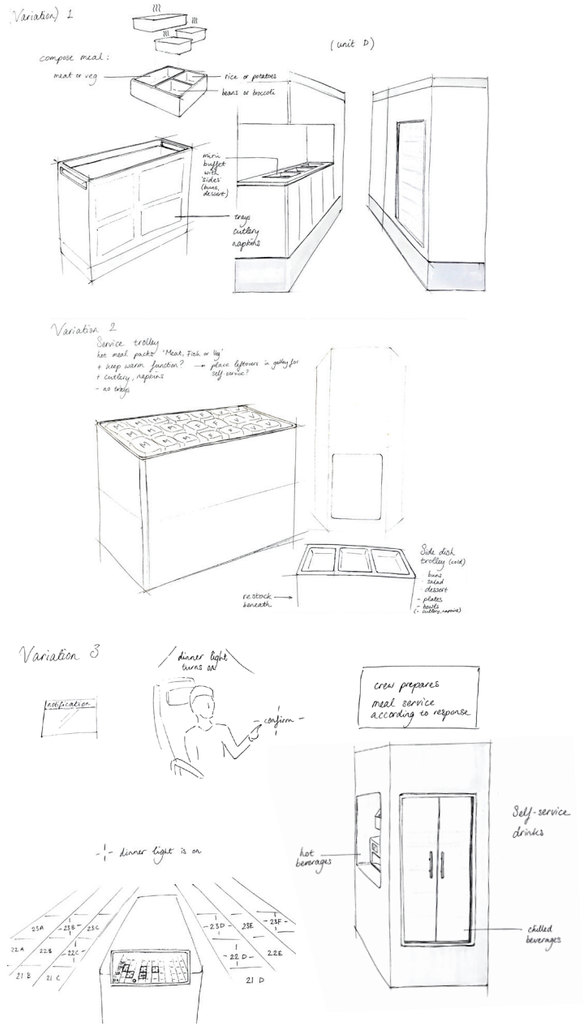
Before continuing, the potential scenario is sketched with a few variations within the final perspective.

Variation 1
The composition of a meal on board consists of three components, which can be variable. These three-component meals are offered during vendor rounds, allowing the passenger to compose a meal with the available options on the spot.

Variation 2
The vendor service consists of two different rounds, warm and cold dishes. The passenger chooses for a warm option during the first vendor round and picks additional sides like a salad or a bun during the other vendor round.

Variation 3
The passenger receives a digital request for the vendor service. By accepting, the passenger is served a (pre-ordered) meal during this vendor round. Passengers who rejected the request will be served during the follow-up vendor round.

With this further exploration regarding the future scenario in the design direction, the final choice is made for the concept. Variation 1 is expected to have a larger impact on the efficiency because it would mean a preparation and service procedure of many separate components in each round. In fact, variation 2 and 3 are combined into one. This perspective is proposed as the new in-flight meal service for the Flying-V, called: **LOOP**.



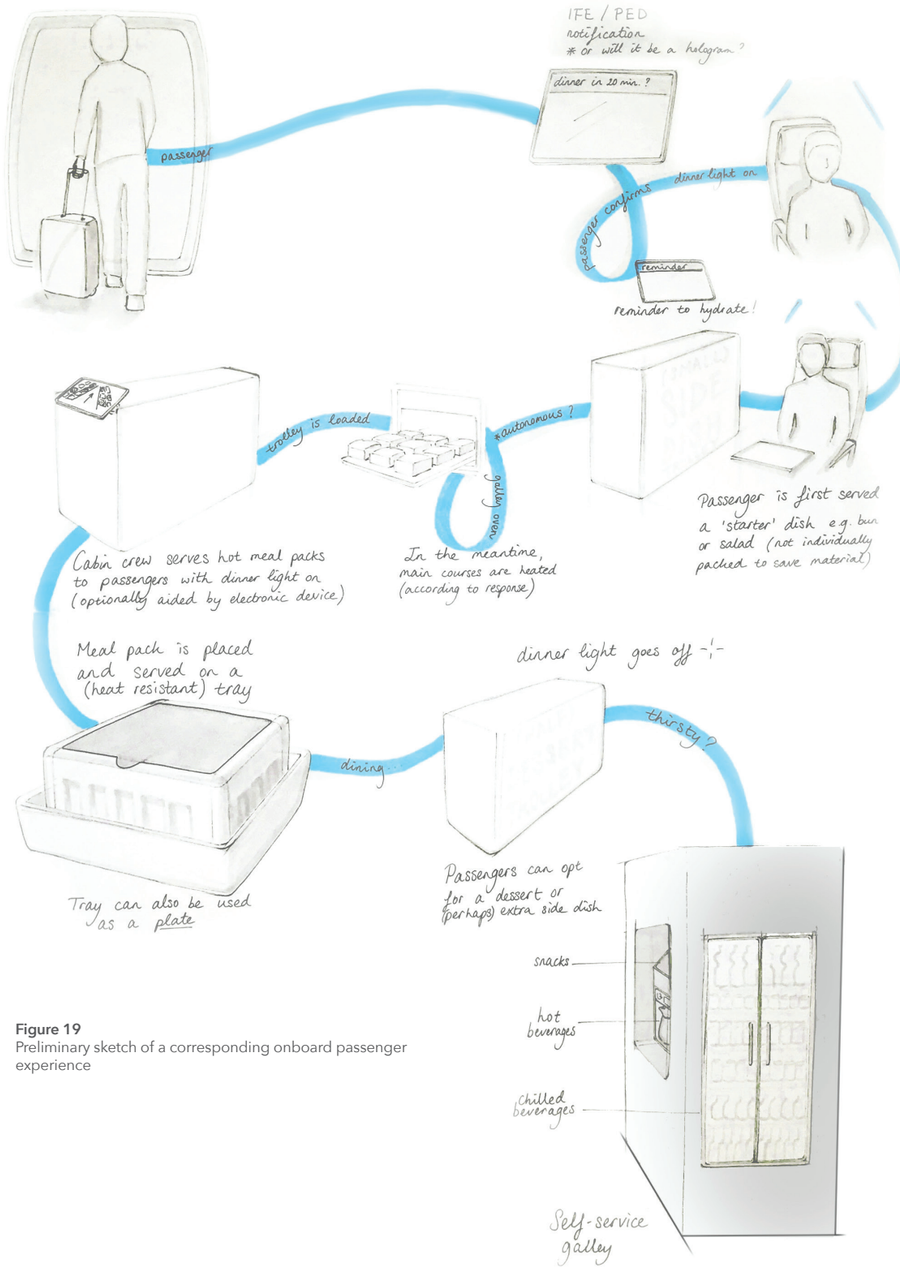


Figure 19
Preliminary sketch of a corresponding onboard passenger experience

5.2 The new value proposition

LOOP: THE EXTENDED IN-FLIGHT DINING EXPERIENCE

Added value of a prolonged dining experience to passenger

The in-flight meal service reveals a few ways in which the passengers can benefit from a better in-flight dining and flight experience in comparison to other meal service solutions.

Passengers are offered the flexibility to eat at desired moments and decide what to eat without being required to determine this all in advance. In fact, the conventional meal service has been split in a group that wants to eat during the first round, another group during the second option and perhaps also a third (group).

The dishes are separately served, prolonging the dining experience to reduce the boredom of passengers during the flight. Passengers who confirmed to have meal service, are given the option to have a starter or side dish. The traditional service is no longer; passengers can experience a 3-course menu with a corresponding course after course rhythm.

By offering self-service in beverages, the passenger's freedom is restricted to beverages only so the area in and around the galley will become controllable, while still offering flexibility to passengers.

Beverages are available in the designated self-service galleys which offers the passengers a refreshing break. As it has been proven that a walk during the flight can significantly contribute to the comfort level of a passenger, this can now be combined with the consumption of a beverage, which also contributes to the distraction of any discomfort.

Added value of flexible service rounds to cabin crew

It is important to ensure that the change in work routine for cabin crew benefits their work experience. The new routine should not impede interaction with the passenger, which is of high importance for the work experience of the cabin crew, as mentioned in chapter 3 as a key takeaway.

The format of several rounds of service allows the airline to provide a more or less 'on-demand' meal service while keeping the increase of workload for cabin crew down. While passengers benefit from an increased flexibility, the work routine of cabin crew shifts from a long service round into multiple shorter rounds. Instead of serving the entire aircraft at once, the cabin crew is more flexible now in their timing to serve passengers, depending on the duration of the flight and responses of the passengers. Although the number of service rounds has incrementally changed, the digital meal selection gives advantages regarding time and workload. The service of asking passengers what they would like to have and preparing their drinks on the spot, is a labour-intensive procedure under time pressure that is now replaced by the interface and a self-service beverage bar. Therefore, the assumption is that this format of meal dishes only will allow cabin crew to perform the same or better quality service.

Added value of separate service to the ecosystem

With the separated service of the courses, the meal tray becomes redundant. The dishes are now directly ready to be individually served as they are packed. Earlier, it was stated by AIM Altitude that the meal trays are loaded onto the aircraft without hot meals and therefore using the space inefficiently. With the removal of trays, this space can now be utilised in a better way.

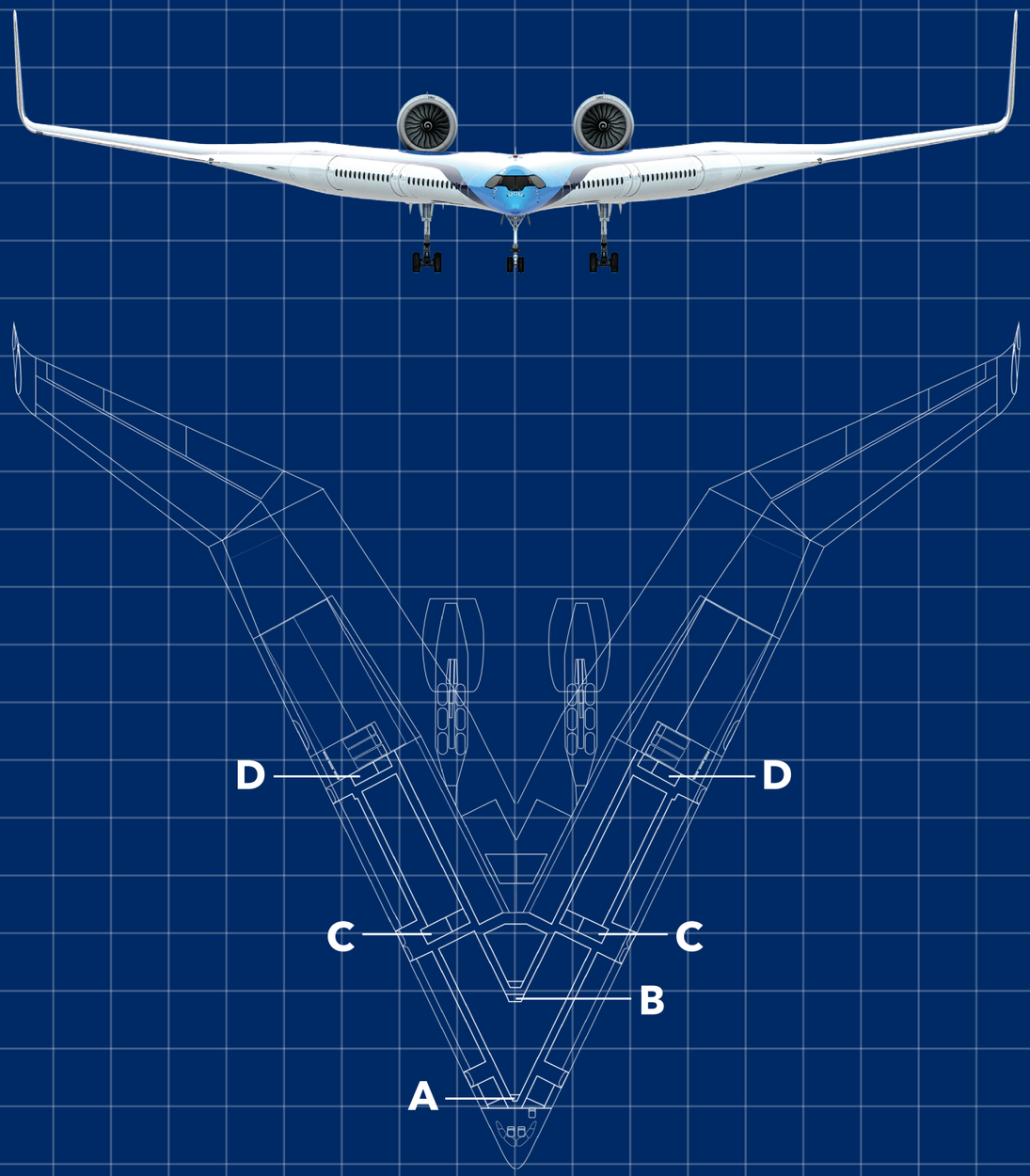
Furthermore, in a traditional way of service, trolleys will not be reloaded on board. By separating the service and loading the cart per meal round, it means that the number of carts - and valuable space - can be incredibly reduced. With a similar principle as the existing ARCA concept, meals are now stored in boxes. The different courses are packed separately and are to be served one by one.

Costs for one meal are expected to be reduced, if not, at least equal to the conventional meal. The caterer can prepare similar dishes which do not require to be assembled on a consumer facing tray. Instead, dishes need to be packed in transport boxes, which is a less detailed process.

Challenges of extending the in-flight dining experience

The foremost challenge within this new value proposition is the logistical division of the meal service rounds and the self-service buffet for beverages. The distribution of passengers grabbing a drink needs to be coordinated in order to prevent inconveniences with the meal service cart. To coordinate passenger movement in a logistical efficient manner, digital measurements are used to, for instance, send passengers a reminder per row to stay hydrated. The area of the self-service beverage buffet can be measured to detect overcrowding and could be combined with a 'warning' symbol to inform passengers, who are at their seat, about the situation and to advise them to grab a drink later.

It is also of utmost importance that passengers who are not able to either use the self-service beverage buffet or the digital meal selection system, can be serviced in an alternative way that meets their special needs. Their requests and the required service should not collide with the meal service round on both operational and spatial level.



Aircraft interior

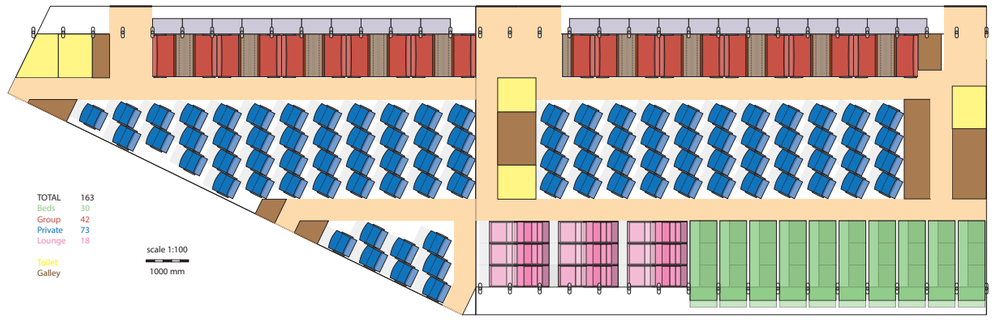
It is assumed that the implementation of the four seat concepts that were introduced in the first chapter, would mean that a business class area is no longer applicable in the layout of the aircraft. The layout wherein the four seat concepts are incorporated, as seen in figure 20, is used as the starting point of the galley design. It should be noted that this layout is submissive to changes and therefore only functions as an indication for the available galley space. With that in mind, there are six galley areas in total to design for. The area of the galleys are sorted by their layout and location and indicated with a letter A, B, C or D.

'Section' A and D are galley kitchens and B and C are self-service beverage buffets. This distinction would prevent overcrowding in one galley where both cabin crew and passengers are present. This way, the passengers have a convenient access as the buffet is more central, while cabin crew have a larger working area at D.

Also, the entrance near C is a two-doors exit, thus offers a more spacious area for passengers to stand and stretch some legs while getting a drink. Also, C is more centrally situated for all passengers, making it highly suitable to be a beverage buffet. Toilets are moved to the 'inner' side of the V, so passengers are facing a pleasant food and drinks occasion when boarding at the C-entrance.

To sum up, there are three kitchen galleys destined for crew use only (A, D-1 and D-2) and three self-service galleys (B, C-1 and C2) for passengers to use. For this thesis, the focus will be on the design of galleys in the C and D area.

Figure 20
The layout of one wing wherein the four seat concepts: staggered individual seats, group seats, sleeping beds and chaise longues, are implemented. The available galley space in this layout is used as the point of departure in the design.



5.3 Scenario of the new process

To provide an elaborative overview of the process and all the involved steps, the scenario is described step by step and illustrated with a cycle divided into six main phases. The redefined meal service is a repetitive service cycle with chronological steps and will be repeated multiple times during the flight.

Before and after each meal service cycle and between cycles during the flight, passengers are reminded with a digital notification to stay hydrated and to get a drink at the self-service buffet for beverages.

1. Preparation: crew initiates service

The service starts with the cabin crew. With a connected cabin and aided with a digital platform, the cabin crew can communicate to passengers and with each other by sending messages and notifications. Whenever ready, the cabin crew sends the first meal service announcement to all passengers.

Each passengers receives the message either on their personal device, which may for instance be a future wearable, or on the built-in IFE-screen of the aircraft seat.

Passengers can choose to have a meal and are presented the menu or they can decide to skip this service round. The passenger selects a starter and main course on the digital interface and receives a confirmation once their order is sent to the galley. Others who skip a meal, leave the meal service cycle at this point.

All meal orders are counted and the computer calculates which meals should be prepared by which galley, taking the seat location, the effective occupation of the ovens and the availability of meal types in each galley into consideration. Based on these factors, the computer calculates a plan for the crew to execute. For instance in case of only a few responses, say a total of 27 passengers, it could be more efficient to prepare the 27 orders in one galley. The computer will send this calculated outcome to the crew so they can prepare the meal service in an efficient way.

2 & 3. Serving the first and main course

The starter dishes are placed into an autonomous cart for service. This self-driving cart allows the cabin crew to perform a quality service with a reduced physical workload. In addition to that, each round is reduced to only serving a single dish, which keeps the service simple. It is important that the cart is able to communicate to humans what its movement is so crew and passengers know what to expect from it. The cart is digitally connected to the cabin computer, which will also calculate the route for the meal service and program each cart with an efficient route. Once the starter dishes are all loaded, the service begins.

In the meantime, the main courses are being heated in the ovens. Once ready, these hot meals will be put on a heat resistant plate to ensure that the passenger can safely place the meal on the table and enjoy the main course.

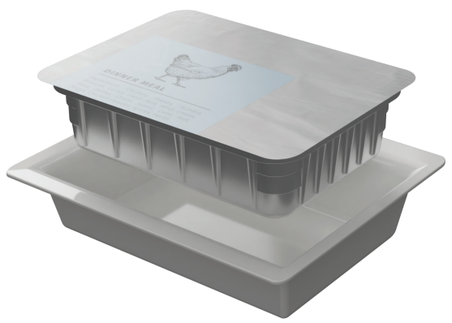


Figure 21
A main course in aluminium packaging, which is obviously hot after being heated in the oven, is placed on a plate and can be served safely to the passenger.

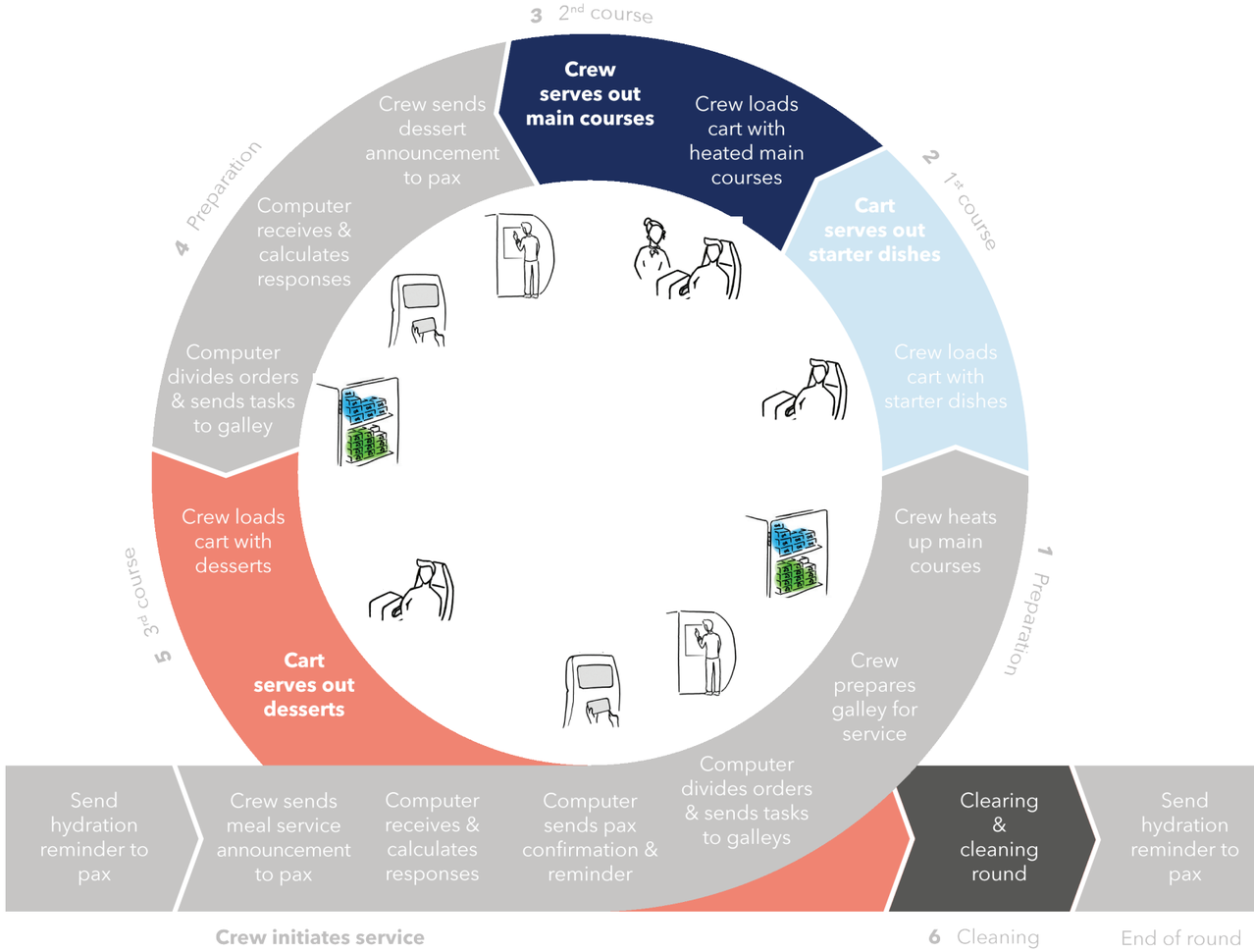


Figure 22
The meal service process illustrated from the cabin crew's perspective.

To transport the meals from the galley to the passenger, the plates are placed in an autonomous cart. With the advanced self-driving technology, it is assumed that the autonomous cart is a reliable innovation for the meal service. If passengers can grab their own meal from the autonomous cart, it would decrease the workload of the cabin attendant immensely. This reduction compensates the workload of the higher frequency in meal service rounds. However, this would mean that the human interaction of the service is replaced. The previously conducted research pointed out that this would most likely affect the quality perception of the flight in a negative manner.

Therefore, the main course is set to be served by the cabin attendant who is aided with the autonomous cart but passengers do not retrieve their own meal. This way, the hot plates are served with care and provides the desired human attention and interaction. The autonomously served starter dishes still mean a reduction of the workload for the cabin crew. This split serves as a starting point for further testing and development and will be evaluated to a greater extent in the passenger validation tests that are following.

Considering the fact that dining passengers are randomly spread over the cabin, it is important to support the cabin crew in serving the right meal to the right passenger. While the autonomous cart already stops at the right seat, the cabin crew is informed by its interface showing where the next stop will be. This serves as a guide for the cabin crew. Additionally, a specific lighting can be used for dining passengers for an enhanced experience and to function as an extra sign for the cabin attendent to see where service is needed.

4 & 5. Preparing and serving dessert

After the main course, the computer sends an announcement to the passengers regarding dessert. Similar to the service in restaurants, passengers have the opportunity to choose for a dessert after dinner or not. Their responses are once again calculated and the computer sends corresponding task plans to the galley. While passengers receive a confirmation that their order is sent, the crew prepares the service of the final course by loading the desserts in the autonomous cart. This autonomous cart is programmed with a new route and will serve the desserts accordingly to the passengers who requested for a dessert.

6. Cleaning

The final phase of the meal cycle is the cleaning service. With an autonomous cart, the waste is collected of each passenger. The self-service aspect of the waste collection is assumed to improve the experience because in this way, the waste can be collected more frequently. Additionally, the waste of other passengers can also be collected, who were not eating.

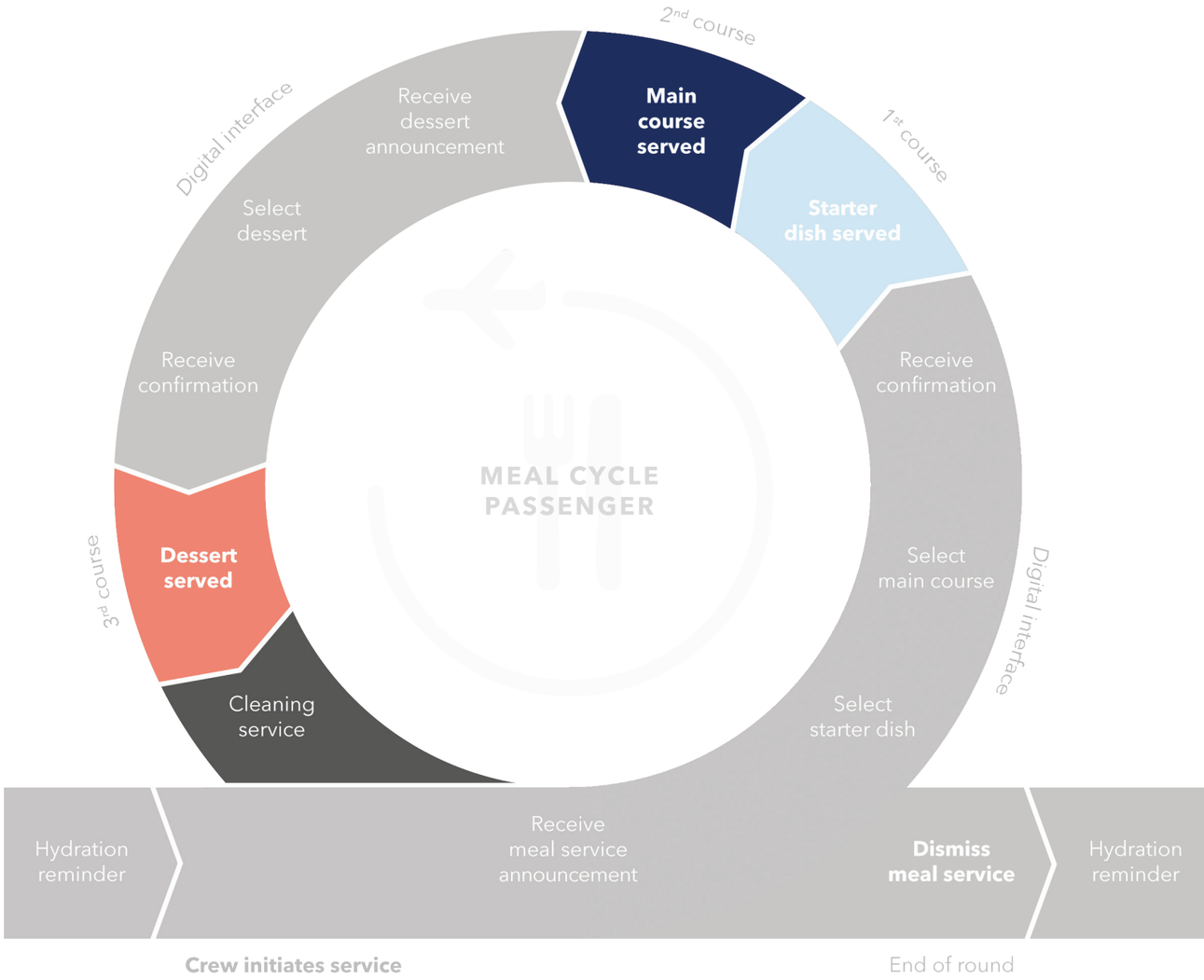


Figure 23
The parallel overview of one meal service cycle from the passenger's perspective. The passenger decides to have a meal or leaves the cycle immediately after the first meal service announcement.

Phase of cycle	Equipment	Difference in following cycle
1. Preparation	Computer Ovens Fridge	• Announcement is sent to remaining passengers • Available stock is different per galley
2. Service of first course	Autonomous cart	• Different route
3. Service of main course	Autonomous cart Heat resistant plates	• Different route
4. Dessert preparation	Computer Fridge	• Available stock is different per galley
5. Service of dessert	Autonomous cart	• Second different route
6. Cleaning	Autonomous cart (Waste compactor)	

Figure 24
Overview of involved cabin equipment indicated per phase and differences in cycles along the flight

Figure 25
An example of a flight journey with three service rounds for dinner and two rounds for the breakfast meal. A passenger can decide to have dinner during the third service round and have some pancakes during the second breakfast round after some sleep.

As mentioned before, this six-phased cycle can be repeated multiple times during the flight, depending on the responses in the previous meal round and how many cycles the total length of the flight can allow. For example, a flight of 6 hours would be less suitable to offer three rounds of dinner. Instead, the cabin crew can decide to offer only two rounds of dinner service and one breakfast round. It could also be possible that all passengers have been served dinner within two rounds of service, so there is no demand for a third round. In another scenario as can be seen in figure 25, for instance during an 11-hour flight, there can be three service rounds for dinner after take-off and two service rounds of breakfast right before landing. A passenger can decide to have dinner during the third service round and have some pancakes for breakfast during the second breakfast round after some sleep, while the second passenger has dinner during the second cycle and breakfast during the first breakfast round.

Alternative scenario: what if all passengers do want to eat at the same time?
It could happen that all passengers confirm during the first round of meal service. To meet this demand, the aircraft galleys should be equipped with sufficient ovens and the cart should have enough capacity. This way, the galley can cope with the workload of the meal preparation for all passengers, similar to the conventional preparation quantity.

On a side note, considering the fact that the Flying-V may have flatbeds on board, would mean that some passengers, who are asleep in the flatbeds, are excluded from the meal service. This means that, if the layout appears to have flatbeds, that the quantity of 314 meals will not be reached in one meal round.

Design of the autonomous cart
For this thesis, the focus will be on the design of the meal service system. Although the autonomous cart plays a substantial role in the service, it is for the same reason not further elaborated in this project, because it would do deficiency to the design considering the limited time for this thesis. For now, the project only concentrates on the preliminary design features in the autonomous cart that are significant for the meal service.

5.4 Detailing of the digital experience

In the previous paragraph, the steps of the passenger's journey are broadly set in the figure of the passenger's perspective meal cycle overview. The steps of the digital interface are copied below:

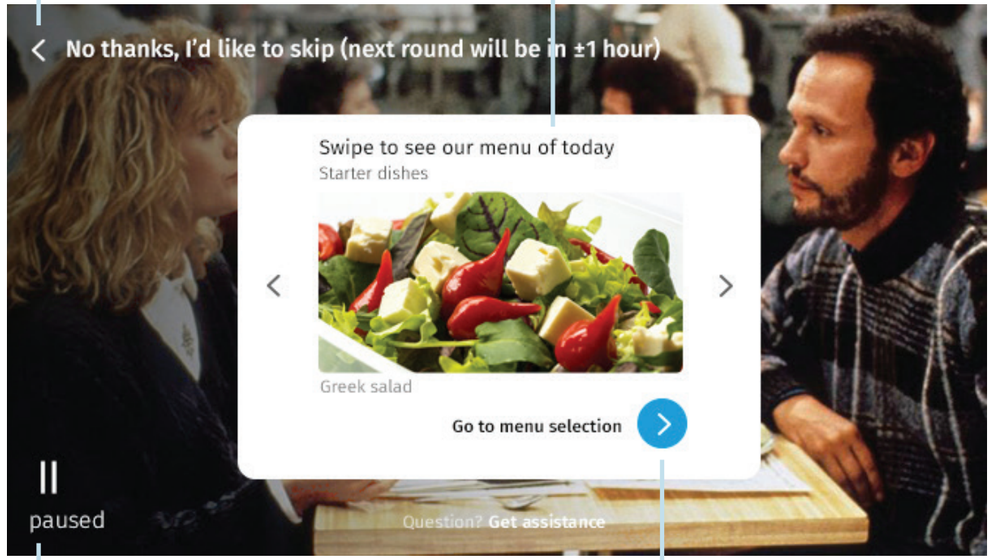
- Receive meal service announcement;
- Select starter dish OR dismiss meal service;
- Select main course;
- Receive confirmation;
- Receive dessert announcement;
- Select dessert;
- Receive confirmation

Since this is a whole new meal service, it is necessary to create a clear interface as part of the passenger experience for everyone to understand. As completion of the concept, the essential parts of the digital aspect in the concept are elaborated in this paragraph.

Figure 26
Passengers receive the service announcement of the cabin crew in the shape of a digital notification bar on top of their IFE-screen. In case the IFE-screen is not in use, the passengers will receive the announcement on their personal handheld device or wearable.

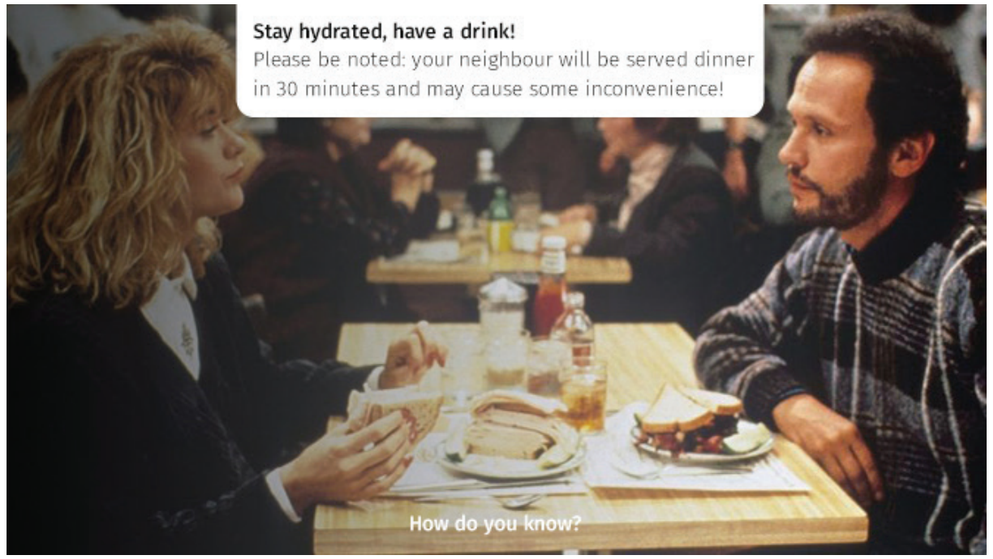
Navigation to the previous step; passengers can swipe through the menu if interested but still skip the meal service round by going back. The passenger is informed about the next round with a time indication.

A pop-up frame appears when the passenger opens the announcement of the meal service round. The passenger can check out nutritional or additional information about the dish if desired.



Any running programmes of the IFE are automatically paused once the passenger has opened the announcement of the meal service round.

Navigation to the next step; passengers can swipe through the menu and 'place an order' in the next step. The availability may change after one round and will be updated in the menu.

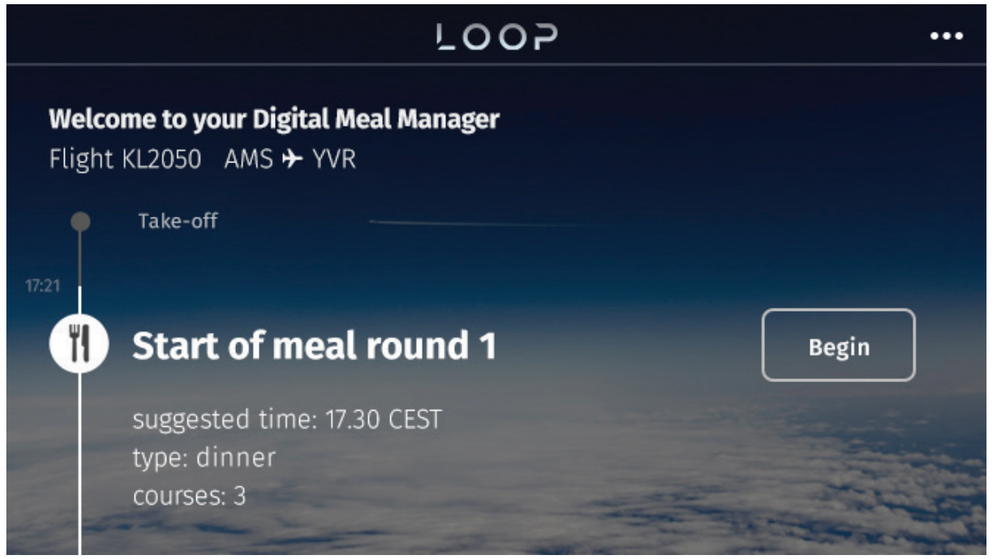


Announcements

Passengers receive announcements of the cabin crew in the shape of a digital notification. For now, it is designed as an announcement appearing in the top of their IFE-screen. In case the IFE-screen is not in use, the passengers will also receive the announcement on their personal handheld device or wearable.

The flexibility of having various passengers eating at different times does mean that some passengers will experience some inconvenience due to their dining neighbour. An informing notification can manage expectations of the coming meal service round and allow passengers to act upon the situation beforehand. For instance, passengers who are dining at the aisle, can cause some accessibility inconvenience for their neighbours. If they are informed, they can go grab a drink or make use of the lavatory before the aisle passenger is being served.

On a different note, such a reminder of inconvenience can also evoke the negative experience of inconvenience or disturbance that the passenger otherwise would not have if not being reminded. Therefore, the digital experience needs to be validated with user tests.

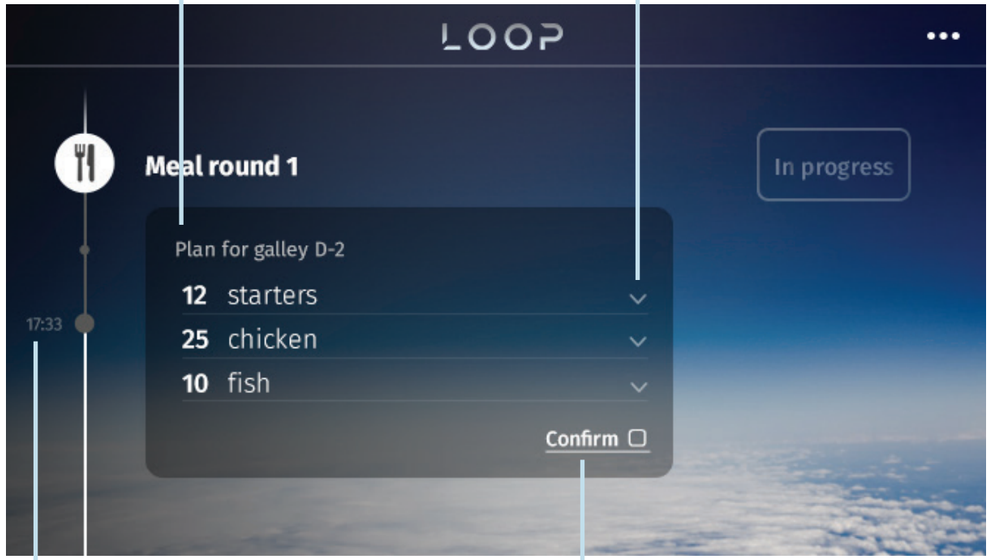


The digital meal manager behind the system

To support the cabin crew in their performance, they are aided with a digital system that helps them managing the OS. It is important that this digital system is compatible with other systems of the connected cabin environment. Therefore the digital meal manager is elaborated with the essential aspects and not designed as a stand-alone application, assuming that it becomes part of one overall system that manages everything in the cabin environment.

The work window displays the task or information of the current step in the timeline. In this case, it is the meal preparation plan of meal round 1, specified for galley D-2.

The cabin crew can access more detailed information about the incoming meal orders regarding the passengers or preparation instructions per meal.



Current time of the ongoing step within process. The timeline with milestones of the flight suggests the cabin crew how to proceed step by step, for instance when to start a meal service round or what the next task is.

Action button to proceed; the displayed information or task requires the cabin crew to take action to proceed. This can be an activation of a certain step that follows or a confirmation before the computer will continue. Either way, the cabin crew is in control of the system.

KEY TAKEAWAYS CHAPTER 5

With the proposed design vision leading the ideation, six main concept directions are created: cabin crew service at your seat [1], anytime self-service galleys [2], takeaway galleys [3], canteen shops [4], buffet [5] and vendor service [6]. Within each concept direction, multiple variations are possible. The concept directions including their variations are evaluated with the design vision in mind and their viability is measured with the set of design guidelines.

The vendor service meets the criteria of the evaluation best of all concept directions and continues as *the extended in-flight dining experience*.

The extended in-flight dining experience is the new value proposition for onboard services in the Flying-V. The principle is that meals are served in several rounds. Passengers can choose to have a meal during a preferred moment or skip a round and have their meal later. The meal service rounds are initiated and coordinated by the cabin crew, which means there is less of an on-demand service pressure for the crew. This way, both passenger and crew are offered the demanded flexibility and control for the meal on board based on an interplay between passenger and crew.

Except for the multiple service rounds, each meal round is also different than the conventional service. The courses of the menu are not displayed on a traditional meal tray but served separate. This prolongation simulates the three-course service in restaurants on the ground. Simultaneously, it provides an extra opportunity for passengers to customise their dining experience.

With the meal service per course, the use of conventional trolleys is fundamentally changed. By packing the courses as single dishes instead of a tray, trolleys are reduced in number. Meal boxes wherein the dishes are stored, can be directly placed into the aircraft and cooled by a fridge. This could be an important reduction in terms of space and costs, because fewer trolleys are needed.

Interior conceptualisation

6.1 Design development of the kitchen

Meal service preparation

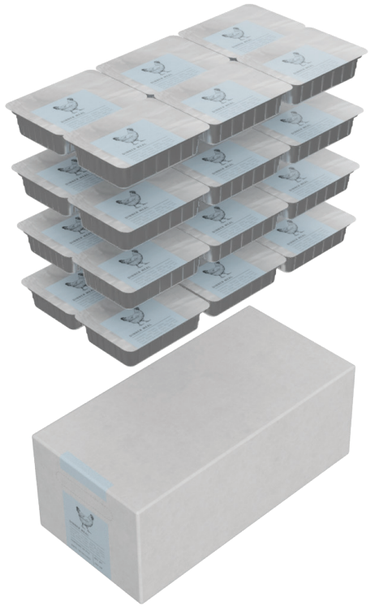
The prolonged dining experience requires a new way of service preparation. First, the meals are no longer put on trays in conventional trolleys. Instead, the dishes are separately packed and come in (reusable) boxes. Each kitchen galley is supplied with different boxes of starters, main courses and desserts. Also the second meals for the flight are provided. Learning from previous flights, the demand is predicted and may therefore result in a varied load per galley.The data of the exact load in each galley is known so the computer can calculate the most efficient preparation plans for the cabin crew. For now, the assumption is made that all three kitchen galleys are equipped with the same, although the design and layout of kitchen galley A at the front of the aircraft is different.

For the preparation of the meal service, the cabin crew takes the right amount of the fridge and heats up the mains in the oven. The kitchen galley is equipped with five ovens, making a total of fifteen ovens on board, which is similar to a Boeing 777-200ER with a capacity of 320 passengers (KLM Our Aircraft, 2020).

Meal boxes

Conventional aluminium meal trays for the hot main courses come in different sizes. Some have a capacity of 300 ml, others have a 360 ml content (Aerexpo, 2020). To design with a safe margin, it is assumed that the required space to store one main course is at least 750 ml. Each meal box contains 24 main courses of this size. Desserts and starters are assumingly smaller than main courses and take up a volume of approximately 300 ml. A meal box of the same size can contain 60 starters or desserts.

This means that there are at least 27 boxes of main courses on board, nine boxes per galley. With 24 boxes of 60 starters or desserts, it means that each galley stores eight boxes of those, good for 240 starters and 240 desserts in one galley. Three galleys (A, D-1 and D-2) make a total of 648 main courses and 1440 starters and desserts, which is sufficient to serve 314 passengers plus crew two times during the flight.



Box dimensions (length x width x height): 500 x 250 x 200 mm

Per galley:

Box	Content	Subtotal
9x	24 main courses	216
8x	60 starters/desserts	480
1x	spare/special meals	*various*

Total on board:
648 main courses
1440 starters/desserts

On a side note, meal sizes are submissive to the airline and airline caterer. With the margin taken, it is actually possible to store 30 (smaller) main courses with packaging dimensions of 160x125x4mm, which is an actual and also common size in conventional aluminium meal trays (Aviopack, 2020). On the other hand, the meal box can also be filled with 20 meals of 1 litre, if some airlines want to offer a larger main course for instance because the data has proven that not everyone wants a meal, but those want, need a bigger portion instead. Eventually, it is important that machine-learning is used to predict demand which results in an efficient load of meals.

The weight of each box is estimated to be 12 kg each, based on 500 gram per main course or 200 gram per dessert or starter dish. According to the NIOSH-method, which is a formula to calculate the maximum weight to lift in certain conditions (Arboportaal, 2020), the estimated conditions of the loading process are good, considering the weight, dimensions and distances. The handle dimensions are according to the NIOSH requirements for manageability.

The exact formula and calculation is elaborated in the appendix.

► see appendix H

Workflow

The galley has a working area for the cabin crew to prepare the meal service. To maximise their workflow, the autonomous carts can be stored underneath so they can easily load the cart to prepare the service. With two carts per galley, the service route begins in both aisles. In a scenario where all passengers are having a meal in the same time, it would mean that each cart is loaded with 52 meals. Compared to conventional trolleys, this is a similar quantity. Assuming that conventional meal trays take more space than single main courses, this quantity is feasible for the future.

The height of the working area and ovens derives from the elbow height while standing. This is based on the antropometric data of Dutch adults between 20 and 60 years old in the DINED database. This height makes the galley also compatible with the conventional trolley, meaning that those trolleys could be used within this design.

Safety pins

To add measurements for turbulence, pins are added in the fridge to keep the meal boxes in their place.

Waste

Taking the Boeing 777-200ER again as the equivalent, means a requirement of eight waste trolleys or compactors in total on board. Therefore, the volume of three conventional trolleys is reserved in each kitchen galley. In this design, the waste space is underneath the ovens. Considering the fact that there is also a waste bin in the self-service galley, this reserved space should be more than enough to also separate the waste for an environmental friendly future.

6.2 Design development of the buffet

Aesthetics

The self-service galley is situated at a two-door entrance/exit of the aircraft. The entrance of passengers during boarding is an important first impression that influences the flight experience. Therefore, the design decision is made to place drinks in sight of the entering passengers.

Moreover, a different appearance enables a clear distinction between the galleys, so it becomes obvious to passengers that they have different purposes: self-service or crew usage. It is important that the self-service usage is understandable for passengers and therefore reflect the stated interaction vision of this project: *During the flight, passengers can feel at ease, as if they are having dinner at a friend's place, where they can find their way to the kitchen on their own initiative*.

To meet the corresponding product qualities of this vision (see chapter 4), a wooden cabinet style is chosen. The wood appearance is tested among participants in a questionnaire to see if this creates a more accessible feeling for its users. The respondents had to rate each design variation on its recognisability, accessibility, comfortability and welcoming appearance. The third appearance in grey scored the lowest in every aspect, so wood can be considered as a contributing factor to the product quality. The second design was rated higher than the first appearance and therefore selected. However, the design was shown in isolation and not placed in the aircraft interior. Therefore, additional contextual testing should be conducted to re-evaluate the first and second design variations as a first impression when boarding the airplane. The full evaluation of the appearance test can be found in the appendix.

► see appendix I

Figure 27
The three variations on the design appearance.

Ergonomy iteration

The initial design was based on conventional trolleys. These carts would be positioned in an onboard fridge with transparent doors. During the flight, the passenger can grab a drink from the cart themselves. The advantages are that the conventional trolley is still put to use and the buffet is easily loaded during the turnaround.

However, the major disadvantage of using trolleys is the position. The drinks are not displayed on eye-level, which means that the first impression will not be the sight of a freshly and fully loaded fridge. Furthermore, the low position requires passengers to bow down before being able to grab a drink. This bending manoeuvre is most likely undesired ergonomic behaviour for the passenger. Especially grabbing the drinks at the bottom would be unpleasant. This ergonomic factor is decisive for the acceptance of self-service. Therefore, the design step is iterated a few more times in order to offer a pleasant self-service experience.

Beverage cassettes

Loading and displaying the beverages have been a starting point for the design. It is crucial that the loading process is made easy for the time on board as well as during the turnaround, because time and space are limited, in contrast to a supermarket for instance. The fridge is now designed to face the two-door aircraft entrance. Except for a pleasant first sight for passengers, it is also for a functional reason. The door of the fridge requires space to open and should be accessible for a fast turnaround process. This way, the fridge door will not block the aisle.

To allow an efficient process of loading and refilling the fridge, a cassette is designed to easily transport and display the beverages. A removable plate in the cassette keeps the content in its place during transport and can be removed by placing it in the back of the cassette behind the beverages. This way, the content can be displayed nicely for passengers on board. If empty, the cassette can be placed in the back of the fridge and does not require a piece by piece reloading. The fridge fits 10 cassettes.

Each cassette has a capacity of 15 regular sized cans (around 330 ml) and 28 slim cans (around 250 ml). The weight is roughly 13 kg with a full content, which meets the maximum lift weight according to the NIOSH-formula.

Total on board		
330 ml cans	30 x 15	450
250 ml cans	30 x 28	840

vs

Total on board of Boeing 777-200ER	
330 ml cans	465
250 ml cans	708

To verify the capacity of the canned sodas, a quick reference calculation is done, based on a load sheet of the Boeing 777-200ER. This is an approximation but shows that the quantities are the right scale.

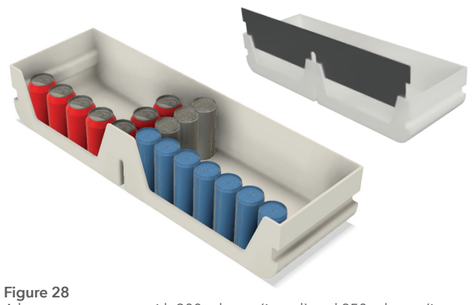


Figure 28
A beverage cassette with 300 ml cans (in red) and 250 ml cans (in blue). A removable plate keeps the cassette's content in place and prevents damage during transport.

Hot beverage machines

For coffee and tea, the galley is equipped with automatic machines. The space behind the machines can be utilised for a water tank and ingredient reservoir. Traditionally, coffee is poured in jugs to serve passengers. Now passengers can grab a drink themselves but this happens one by one. To accelerate this operation and prevent waiting lines, the galley design allows a third coffee machine to be placed between the two existing machines. However, placing three machines in a row may be so close to each other that the usage is less convenient. The design of the coffeemaker also allows the usage of jugs. With an automatic detection of the content, the machine can continuously refill a jug automatically. This way, the left machine could for example be used for hot water and the right machine for making coffee.

There is more research needed to determine the sufficiency of the machines regarding usability and effiency. The use of jugs in self-service needs to be explored further to see how much it affects efficiency, but also taste, hygiene and safety. For now, the design consists of two coffeemakers, making it a total of six on board, which is equal to a Boeing 777-200ER.

Economic opportunities

Of course it is questionable to allow passengers to drink without limits, especially in terms of alcoholic beverages. Therefore, further testing is required in order to set the 'rules'. For now, the design incorporates a screen next to the hot beverages. This is the side of the fridge, which is an unused surface centralised between the key attributes of the galley. This screen is placed for any digital support that the passenger can call upon if necessary, such as checking what is on offer. The screen is also usable for payment by card, wearable or any other future payment device, which is made possible with the onboard digital connectivity.

With that, multiple sales strategies are possible. Passengers can for instance buy a subscription with their ticket for a certain amount or type of drinks in advance or pay per drink on board. Legal drinking age can be checked simultaneously with the registration of the payment, making self-service friendly for everybody.

A set of technical drawings from the galley designs and fridge cassette with outline dimensions can be found in the appendix.

► see appendix J

Figure 29
Again, safety pins are added in the fridge to cope with turbulence during the flight. These pins lock the cassettes on their place, likewise in the kitchen galley. This makes the cassette also usable in the kitchen galley. Using the same mechanism, the cassettes can also function as storage trays for the fridge in galley D.

6.3 Aircraft interior in Virtual Reality

The design of galley C and D are created with a focus on the functionality in relation to the extended in-flight dining experience. To showcase the designed outcome in relation to the cabin environment at its best, the galleys are placed into Virtual Reality. This allows a person to access a three-dimensional space by means of wearing a VR-headset. With a three-dimensional simulation of the aircraft's cabin environment, more insights can be gathered about the concept.

For this project, Unreal Engine 4 is used and the HTC Vive Pro.

Detailing

The cabin interior is focussing on the area in the aircraft's wing between galley section C and D. The major difference between the designed lay-out of the cabin and the cabin in virtual reality is the seat configuration. Instead of the four Flying-V seat concepts, conventional seats are placed in a ten-abreast configuration. In other words, three seats are placed at each side, four in the middle and two aisles inbetween. Therefore, it should be taken into account that this difference may be of influence concerning the virtual experience. Moreover, the seat is positioned over the axe of the wing and thus not facing the direction of flight. In reality, this angle deviation from the direction of flight would be too large to travel safely. However, the main focus for the virtual reality environment is the galley. The number of rows is yet the same as in the lay-out of the aircraft as presented in chapter 5.2.

Figure 30
A three-dimensional scene from the cabin interior. In the pursuit of relaxation, ambient light is added to create a soothing cabin environment.

Figure 31
The kitchen galley located in area D. The door of the fridge can be opened by the 'player' in virtual reality, as well as the doors of the ovens. A permanent screen is added next to the ovens, which is otherwise unused wall space. With that, the crew has access to the digital system to coordinate the onboard services.

Figure 32
The monuments placed in the cabin environment. The empty space in the back is occupied with passenger seats or beds in reality.

Figure 33
Translucent panels are added into the interior to separate the area. This way, passengers seated close to the self-service galley will not be disturbed by its visitors. Passengers sitting at the exit may experience disturbance though, except that the starting point was that these three seats will be group seats and thus not facing the galley.

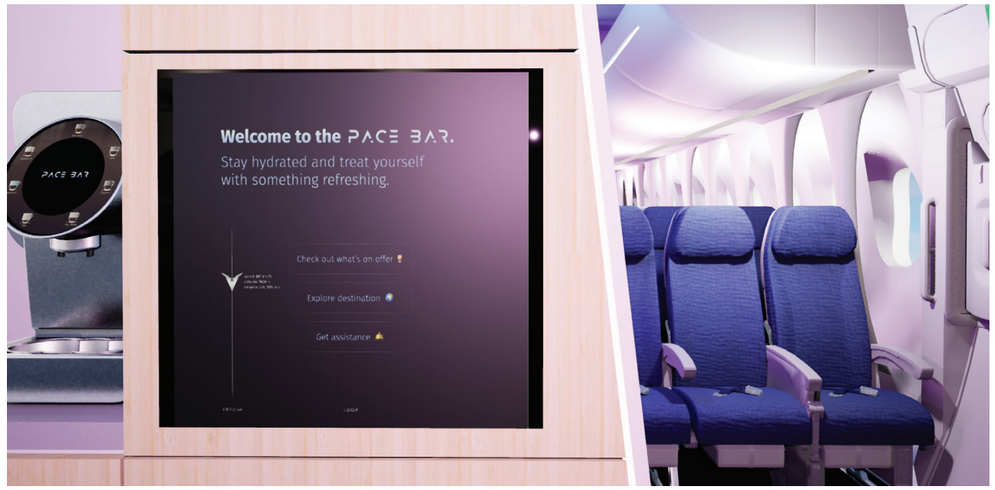


Figure 34
The screens of the cabinet and hot beverages machines are updated.

Figure 35
Boarding passengers will be welcomed with the sight of some refreshing drinks.

KEY TAKEAWAYS CHAPTER 6

For the design of the onboard services in the Flying-V, the Boeing 777-200ER is taken as an equivalent for the quantities on board. In the meal service preparation, the meals are now stored per course in a box. The boxes are placed securely in fridges in each kitchen galley on board, where the cabin crew heats up the orders per meal round and places the meals in the autonomous cart. The dimensions of the meals, the fridge and the galley are based on the Boeing 777-200ER as mentioned and the anthropometric data of Dutch adults.

The self-service galley for beverages makes use of cassettes that can be easily loaded into the fridge as a whole. This way, the beverages can be easily transported in cassettes from caterer to aircraft and the galley is loaded faster during the turnaround of the aircraft. During the flight, the cassettes are locked with a pin so they will not fall out of the fridge. Two machines are implemented in the design for hot beverages. The drip tray allows the machine to prepare for two cups a time and can also be retracted to fit a jug. Further research is necessary to evaluate the efficiency of the machines, taste, hygiene and also safety. For now, the number of machines is equal to the Boeing 777-200ER.

A wooden texture is added to the self-service galley design to create a deviating appearance from the kitchen galley. The appearance of the self-service galley has been tested with a questionnaire. Three designs were rated on their recognisability, accessibility, comfortability and welcoming appearance. There were two designs with a wooden texture that scored significantly higher than the third design without wooden texture. The design with the highest rating is chosen.

To showcase the designed galleys in relation to the cabin environment, the designs are translated into Virtual Reality. This allows a person to access a three-dimensional space by means of wearing a VR-headset. With a three-dimensional simulation of the aircraft's cabin environment, more insights can be gathered about the concept as well. The major difference in the virtual reality environment is the seat configuration. Instead of the lay-out with the four seat concepts, conventional seats are placed in the cabin. This should be taken into account when evaluating the cabin interior, as it may be influencing the perception of the galley design.

7 Validation

7.1 Validation of the passenger journey

To validate the applicability and value of the renewed OS, different tests were performed. First, a passenger validation test is conducted by means of a questionnaire. Secondly, cabin experts are consulted regarding the operational steps of the designed service. As a third, the 'physical' cabin experience is tested in Virtual Reality. These three tests give insights regarding the three aspects of the project scope, as described in the beginning of this thesis: Passenger, System and Cabin Interior.

Validation of the passenger journey

The goal of the test is to validate the inclusivity and functionality of the system design. The participants evaluate how they experience the Onboard Services as a passenger, and more specifically, whether passengers experience a positive effect during the meal service.

Research question

- How does the meal service concept influence the interaction between passenger and cabin attendant?
- What design features do passengers think that will contribute to the (food) experience?

Test set-up

The onboard scenario of the passenger's inflight meal service is simulated step by step in a digital questionnaire. Each step of the service procedure is shown in images and descriptions. This starts with the first announcement, wherein the participants can make their first decision: to eat or not to eat, similar to the reality. Depending on their answer, the questionnaire continues with the corresponding next step. Eventually every participant goes through the scenario of one meal service round, regardless their first choice.

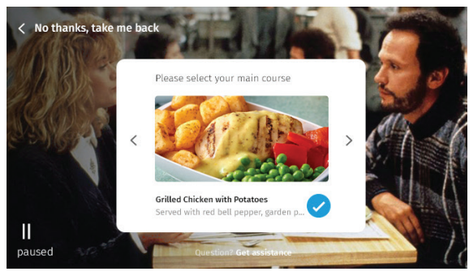


Figure 36
Illustration of a digital interface in the test

After the completion of a meal round, the participant rates the experience by means of the evaluation criteria, in both a qualitative and quantitative manner using Likert's scale (Likert, 1932).

The evaluation criteria used in the questionnaire are based on the Customer Experience values formulated in the design guidelines of chapter 4.

1. Level of time convenience
2. Level of food customisation
3. User friendliness
4. Ergonomic advantage
5. Service

A full description of the method and test results can be read in the appendix.

► see appendix K

Results

With a total of 58 responses, the respondents vary in their age from 20 to 72 years old. The majority (33 out of 58) flies more than once a year and over two-third of the participants flies long distances.

The average scores vary between a 3,3 and 4,3 on a 5-point Likert scale, as can be seen in the table. It is the autonomous food cart that scores less than the other rated aspects of the concept. With an average rating of 3,3 it scores relatively low for the appreciation of the autonomous food cart. The rating of the meal concept aspects are close to each other, between a 4,1 and 4,3 on average. Also the human interaction appears to be of equal value, which is an important indication for the meal service. The charts of each rating can be found in the appendix.

Rated value	Average score
(Digital) meal	**4,1**
Interface understandability	**4,2**
3-course menu	**4,3**
Courses served separately	**4,1**
(Self-service) interaction with an autonomous food cart	**3,5**
Appreciation of an autonomous food cart	**3,3**
Human interaction with a cabin attendant serving the main course	**4,2**

The final score of the questionnaire concerns the overall opinion regarding the meal service rounds combined with self-service beverages. To allow the respondents a bit more room for nuancing their answer, this value was rated on a 7-point Likert scale, and scored as much as a **6,0** on average. The actual responses are shown in figure 37.

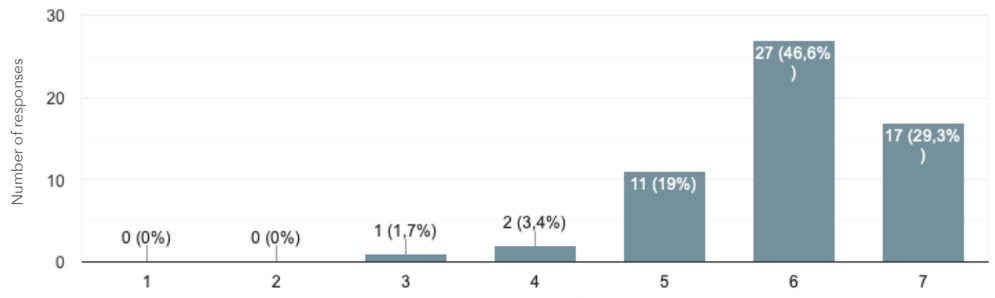


Figure 37
Score given of overall opinion on the meal service process and self-service beverages (7-point Likert scale where 1 means 'I do not like it at all' and 7 means 'I like it very much')

The collected passenger input can be categorised in a few aspects. The similarities and differences in their answers are analysed and the most critical comments are elicited per category below as the following concerns:

Digital experience
One of the concerns that passengers might have with these meal rounds is to unvoluntarily skip them all because of being asleep. Unlike a cabin attendant, the digital announcement does not tap them on the shoulders to wake them up. Respondents have indicated that a timeline or overview with the scheduled meal service rounds is appreciated so they know how many rounds they can skip.

Since the progress of the scenario depends on the answer of the participant, only ten responses are gathered about the 'hydration reminder' for passengers who decided to skip the first meal round. This small respond gives already interesting results. Six out of ten have expressed themselves in a negative tone about the reminder, while four respondents are enthusiastic about the addition.

Meal service
There is also a social concern among the respondents. Although the concept of multiple service rounds is received well, some passengers are afraid to disturb others with

"It is a good way to get moving, I also like the idea of being able to do something yourself during the flight." – participant

their food smell or sound when eating, which is a consequence of dining at different moments. Also, the autonomous cart gives another social concern. Passengers are worried to bother their neighbour to help them reaching the autonomous cart if they are sitting in the window seat themselves.

Self-service beverage buffet
The self-service is generally well received among the respondents, as they explain that it adds a sense of control and freedom. It is a continuous point of attention though to coordinate the movement of passengers carefully and prevent overcrowded aisles. For this, the beverage machines must operate smoothly so there is no waiting line and there must be enough space to walk around each other, because people are afraid to spill. Especially the combination with the autonomous cart concerns the passenger because they wonder how it will behave whilst standing and walking in the aisle together. Therefore, some would like to drink their beverage before returning back to their seat.

Conclusion

The test is conducted anonymously without collecting data regarding gender and ethnicity. Therefore no relation with the results can be drawn from there. The results are probably represented by a Dutch majority, which could be of influence on the perceived experience. However, considering the individual focus of the meal concept and the international environment of the aircraft, the ethnicity and also gender, are neglected for now.

How does the meal service concept influence the interaction between passenger and cabin attendant?

A few conclusions can be drawn from the test regarding the meal service concept. In general, it is positively received and contributes well to the passenger's experience. Respondents have indicated that this gives them a sense of control during their flight and enjoy the freedom of being able to grab a drink themselves. Also, the fact that self-service enables physical activity, is appreciated.

The respondents do not seem to have any trouble with using a digital system to make their meal choice, however, there are some specific concerns about the autonomous cart. In general, there is little resistance to the cart. Many are convinced that this contributes to the efficiency of the service and thus see benefit for their own experience. The relatively lower average than the other scores, is most likely explainable by the fact that it is new and unknown. However, the respondents are concerned that sitting in the window seat will be the complete opposite and far from efficient. Considering the seat configuration of the Flying-V, it is actually less of a concern. The staggered position of the individual seat makes it easier for the passenger in the middle to reach out to the aisle. The passengers in the group seat are already sitting in a social mode, also that should not be a problem to reach out to the aisle. The major challenge is the window seat of the chaise longue. Not only does this passenger have to reach out over two passengers, the chaise longue is also positioned at different heights, making it crucial to address in the design of the autonomous cart.

Nevertheless, the autonomous cart cannot replace the cabin attendant. The human interaction with the cabin attendant serving the main course, is much appreciated, as it scores a 4,2 out of 5. This is higher than the appreciation for the autonomous cart, which scored the lowest average of 3,3 out of 5. Although it is considered to be less personal, as mentioned earlier, there is actually little to no resistance to the cart. This is most likely because of the efficiency that the respondents see in the autonomous cart. However, it is important that the usage is truly practical for them, for the reason that they like to be more independent. Only then, passengers would see it as a benefit.

What design features do passengers think that will contribute to the (food) experience?

With an average score of 6,0 out of 7 on the overall concept, it may be safe to say that the meal round and self-service for beverages is generally well-received. It is seen as an opportunity for physical activity, therefore the area should be safe to have people walking around each other. The area chosen at entrance C is highly suitable as it does offer passengers the space to grab a drink and move a little.

The self-service aspect does require a form of protocol that assures a safe flow of passengers moving around in the cabin, which is also mentioned by the respondents. A digital indicator that informs the passenger about the situation, e.g. whether it is busy in the galley or not, should be added. Also, specific times when the self-service buffet is not accessible, should be indicated. This can be done by using the existing seatbelt lights, for instance during turbulence. However, another indicator might be considered when, for example, the access restriction applies to the buffet and not the lavatory.

Furthermore, respondents have indicated that they wish to have more information regarding the scheduled meal rounds, because they are afraid to accidentally skip them all. An overview of meal rounds during the entire flight should be added to the digital experience.

Although the hydration reminder is only commented by ten respondents, it is evident that it must change. Six people consider it to be an annoying and intimidating announcement, whilst the other four think it is helpful. A possible underlying influence may be the language of the announcement and the style of language. The test is conducted in English, but in the future concept, it would be more likely to allow the passenger to select its preferred language. Also, a playful formulation of the announcement or a formal style can make a difference in acceptance. Either way, the reminder is more perceived as negative than positive and therefore requires further research.

7.2 Validation of the system

To validate the applicability and fit of the designed system, the concept is evaluated by cabin attendants and cabin experts from various backgrounds. The cabin crew as well as cabin researchers were asked to provide feedback into the practical and theoretical usefulness of the system.

Research question

How does the meal service concept influence the galley operations of the cabin crew?

Test set-up

The test set-up is similar to the previously conducted questionnaire and simulates a journey through the operational steps of one meal cycle. The journey starts after take-off in the kitchen galley, from the perspective of a cabin attendant. The steps in the service are supported with digital interface illustrations that manage the meal service rounds.

After going through one meal service round, the participants evaluate the concept in both a qualitative and quantitative manner using Likert's scale.

The evaluation criteria in the test are based on the 'Airline Operation' values formulated in the design guidelines of chapter 4.

1. Ecosystem fit
2. Cabin crew friendliness
3. Efficiency

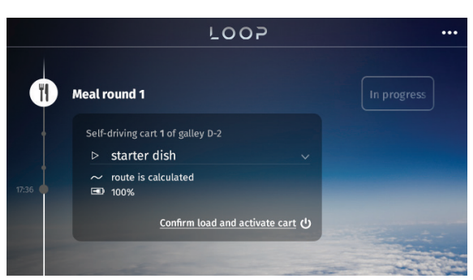


Figure 38
Illustration of a digital interface in the test

The additional description and test results can be read in the appendix.

► see appendix L

Results

In total, 28 responses are gathered from cabin experts with different backgrounds. The various expertise domains and the number of participants from each domain is shown below.

Expertise area	
Aviation industry journalism	**1**
Cabin crew	**20**
Cabin designer/researcher/R&D	**7**

The following values have been rated on a 5-point Likert scale. The averages are shown in the table.

Rated value	Average score
(Digital) support	**3,6**
Interface understandability	**4,2**
Preparing courses separate	**3,9**
Usage of autonomous cart	**3,5**
Serving the main course	**4,1**
Split between food and beverages	**2,8**

The score that really stands out is the rating of the split between food and beverages in the work experience. The chart, see figure 39, shows the spread between the given answers and is clearly concentrated on the left side of the scale. Isolating the cabin crew responses from the test, shows that the average among crew *only* is even lower: 2,6 out of 5. In the qualitative results, the underlying reasoning for the low score is elicited.

Digital system
The digital interfaces of the test have scored best, but sending digital reminders to passengers is discouraged by the majority of the respondents, as it is considered to be disturbing.

Galley design
The results regarding the galley design are minimal. Two cabin attendants have indicated that it would be better to have the ovens and fridge at the same side, while most respondents have indicated that more workspace would be mostly appreciated. The question regarding a fixed screen or handheld device for operating the digital system has resulted in thirteen respondents who prefer a handheld and nine would choose for a fixed screen in the galley. The other six participants would really like to have both.

Finally, the overall opinion is asked by means of a 7-point Likert scale. The respondents have rated the process of the complete meal round with a **5,1** out of 7 on average.

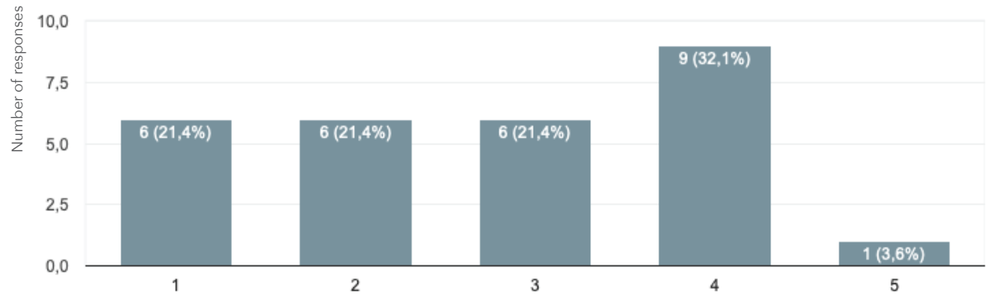


Figure 39
Score given of the split between food and beverages in the work experience (5-point Likert scale where 1 means 'I do not like it at all' and 5 means 'I like it very much')

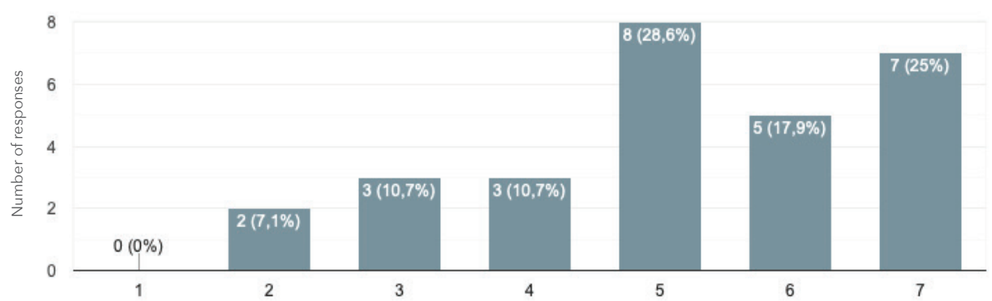


Figure 40
Score given of overall opinion on the meal service process and self-service beverages (7-point Likert scale where 1 means 'I do not like it at all' and 7 means 'I like it very much')

"Hygienic that you only take out of the fridge what you need." – cabin attendant

The qualitative results of the test are categorized in a few topics. In the analysis, the similarities and differences are addressed and the following main comments have come forward:

Personal interaction
The major concern among the respondents is the personal service. More than half of the group has mentioned at least once that they would dislike a reduction of interaction between crew and passenger. Personal contact is key in their work experience and also the flight experience of the passenger. Despite the fact that respondents recognise a lowered workload and an easy way of preparing meal service, the introduction of the autonomous cart and splitting off beverages is foremost seen as a reduction of these important contact moments. Moreover, without cabin crew, passengers in the furthest window seat might have difficulty reaching the autonomous cart or getting themselves a drink from the self-service buffet.

Passenger mistakes
Another concern that rises, is the passenger autonomy. The system relies on the passenger taking what is meant for them. If not, the cabin crew might have to resolve situations with unhappy passengers. Passengers might also change their mind, for instance by seeing someone else's meal, which could also become a problem for the cabin crew to solve.

Self-service traffic
Safety remains a concern of the cabin crew, which is their primary reason being on board. A self-service buffet for beverages causes a lot of movement in the cabin, which can lead to overcrowded galleys or busy aisles. Also, respondents are concerned about the passengers while they are having a hot beverage in their hand and trying to pass each other or the autonomous cart. Especially during a meal round, it could be too busy, having passengers moving in and out for a drink alongside their meal and automous carts in the aisle. This adds another reason for the low score of the split between food and beverages in the service, as it may cause more traffic during the meal round.

One other subject that is frequently mentioned by respondents is the hygienic aspect of the meal service concept. The beverage buffet and autonomous cart would be a hygienic way to offer OS. In addition to that, the quality of the food is better maintained by storing and preparing the courses separate.

Conclusion

How does the meal service concept influence the galley operations of the cabin crew?

Overall, the score of a 5,1 out of 7 is a positive indication for the acceptance of the concept by the cabin experts in general. It seems that the meal service concept affects the personal interaction between passenger and crew foremost, being one of the most frequently mentioned concerns. Although the autonomous cart and self-service buffet would decrease the workload, the respondents and foremost the cabin crew, are not fond of reducing the moments of service. Personal service is a way for airlines to distinct themselves and a reduction of personal contact would affect this. However, this also means that it could differ per airline how much this would be a concern. Nevertheless, it can be concluded that the reduction of personal contact influences the work experience in a negative manner.

For that reason, it could be considered to apply the following changes to the meal service concept:

The service of the starter and dessert can be 'guided' by the cabin attendant, similar to the service of the main course. With the use of a self-driving cart, the physical workload of pushing a cart is then still reduced, while moments of personal contact with the passenger are maintained or even increased in frequence.

Furthermore, the concern about passengers making mistakes with the autonomous cart is taken away. Additionally, if passengers do change their mind, an alternative could be offered by using data-based prediction to prepare a few extra meals during each service round, in case such a situation occurs occasionally.

The self-service of beverages is considered inconvenient during meal rounds when it is already busy. Therefore, it could be an improvement to simply serve water - for instance in refillable bottles - together with the meal service. For that, it would be necessary to dive into the future possibilities of clean water taps on board.

As it comes to feedback on the galley design, respondents have indicated that the given images in the test were insufficient to give input. Therefore, a different test should be conducted wherein the participant can have a better view on the design in relation to the cabin environment. One thing that can be stated is that both options of having a handheld device or fixed screen in the galley to operate the digital system are popular. Therefore, both could be implemented in the galley, either a docking station or fixed screen. However, costs and space should be further evaluated in order to make a design decision.

Finally, it is mostly discouraged to implement reminders for passengers to make use of the self-service buffet, neither per seat row, as it is considered to be disturbing for the passenger journey. More subtle reminders or notifications may be explored, e.g. ambient lights changing blue for hydration.

Naturally, these considerations require further exploration on their turn, in terms of operational sequence as well as user experience, in order to improve the concept.

7.3 Validation in Virtual Reality

The aesthetical appearance and function of the designed beverage buffet in relation to the cabin environment is tested in Virtual Reality. The participants evaluate how they experience the aircraft interior as a passenger or cabin crew member.

Research question

- How does the galley design contribute to the experience of the passenger and cabin attendant in the Flying-V?
- What design features will contribute to the (food) experience?

Test set-up

Virtual Reality test sessions were set up one on one. Every participant is briefly introduced to the Flying-V and the functional reasoning behind the design of the galley concept. During the test, the participants walked around in the virtual cabin environment and were able to open the doors of the fridges and ovens. Also, they could pick up a coffee cup or soda can. While doing that, the participants had to say out loud what they thought and were asked a few questions about how they experienced the environment afterwards.

Figure 41
The virtual reality test setup in the crew centre at Schiphol Airport.

Results

In total, fourteen sessions were held with cabin crew members (10) and passengers (4).

The following product qualities, which derive from the design vision in chapter 4: *recognisable, comfortable, accessible and welcoming* have been rated on a 5-point Likert scale. The answers are generally positive. Despite the varying heights of participants from 1,54 meter to 1,94 meter, the products are rated accessible to reach and to use. The observation of the participants during the test has indicated though that some dimensions in the design could be improved.

A detailed elaboration of the method and test results can be found in the appendix.

► see appendix M

"I can totally imagine that robots will be used in this aircraft as well."
– cabin attendant

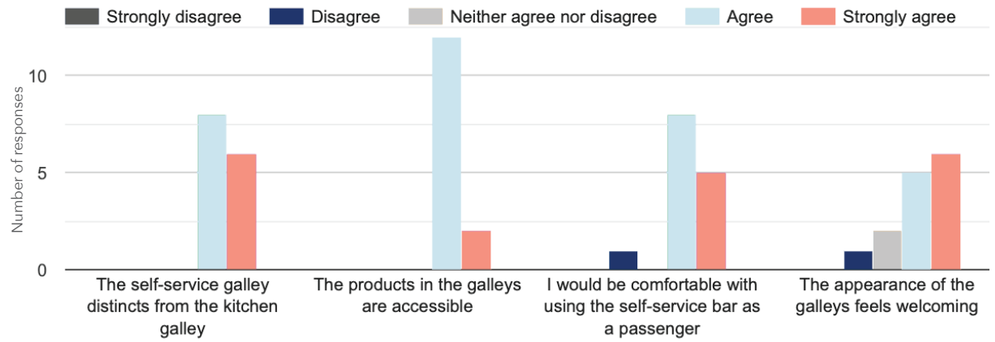


Figure 42
Score given of the values (5-point Likert scale where 1 means 'Strongly disagree' and 5 means 'Strongly agree')

Conclusion

The qualitative answers of the participants are analysed and sorted by the perspective of a passenger or cabin crew.

During the tests, most participants were possibly slightly overwhelmed by the cabin environment. Although some cabin attendants had experience with Virtual Reality, this test still seemed to have a wow-factor. This could have influenced the results of the test, as some details become distracting from the galley design. The seat configuration in Virtual Reality deviates from the designed lay-out, which means that the validation of the whole cabin interior experience cannot be fully confirmed by this test.

How does the galley design contribute to the experience of the passenger and cabin attendant in the Flying-V?

Either way, the participants were generally excited about the cabin interior. Many have mentioned that the self-service area looks spacious and that the overall design feels modern and clean. Also the lighting and the colored details of the lights have been noticed by participants, which were positively commented.

A few cabin attendants are hesitant regarding the self-service of beverages. They are afraid that passengers will take more than usual and that too many passengers will move around, which may affect the safety.

Figure 43
Participants use the controller to grab a coffee cup and can throw it away in the bin.

Figure 44
The participant opens a door and can get a drink from the fridge.

What design features will contribute to the (food) experience?

Validation with the cabin crew has pointed out that the designed countertop workspace is probably too small, especially when working with more colleagues in one galley. Although this viewpoint is most likely based on their experience with the existing meal preparation process, it is highly recommended to increase the countertop workspace. For this, more in-depth research is needed regarding the new service rounds and detailed scenario of the preparation in order to define the optimal workflow and workplace for the cabin crew.

During the test, it was also observed that the height of the screen in the self-service bar is placed too low. This is now placed on equal height as the coffee machine, which is fine for getting a drink but clearly not for reading. The height of the participants has been gathered, which is various, but this is mostly observed by participants taller than 1,75m. Therefore it is recommended to further test with a main focus on the ergonomic aspects and to place the interface on an (eye-)level that is usable for an international audience with different heights.

KEY TAKEAWAYS CHAPTER 7

Three different tests are conducted to validate the applicability and value of the renewed OS. Two tests are conducted by means of a questionnaire with different user groups and the third test validates the design in Virtual Reality. The resulting outcomes have given insights regarding three key aspects of the project scope, which are the *passenger, system and interior.*

The opinion on the overall OS concept is generally positive. From a passenger perspective, the concept scores a solid 6,0 on a 7-point Likert scale and is rated with a 5,1 out of 7 on average by cabin experts. Further analysis of the questionnaires outcomes have given valuable insights in the stakeholders by showing similarities and differences between the passenger and cabin expert.

One of the similarities is the digital experience with reminder notifications. Whilst only ten passengers have given their opinion on a hydration reminder, six were against it. Comparing this with the cabin experts, the majority of them was negative, too. Although hydration reminders are perceived not so well, some passengers are concerned to accidentally miss every meal round notification. Adding an overview of the meal rounds during the flight is suggested.

Strengthened by the lowest score throughout the test, the cabin experts are genuinely concerned about the lack of personal interaction. With the use of self-service beverage buffets and autonomous carts, food is separated from beverages and personal contact moments would then be reduced. Additionally, there is no control on who takes what or how much.

However, from a passenger perspective, the sense of control and ability to do something freely is much appreciated. There is some hesitation among passengers though because they do not want to disturb or be disturbed by their neighbours too often when getting out of their seat for instance, or be the only one in the row having a meal, for instance. Nevertheless, they enjoy the thought of grabbing a drink and stretch their legs in a designated area.

The most frequently commented aspect is probably traffic. The self-driving carts could be disrupted by constantly walking passengers. Also, it might become too busy in the self-service galleys. For the onboard safety, movement needs to be coordinated. An indicator showing how busy it is or 'occupied' sign, similar to lavatories, could be a regulation example and should be further tested.

Using Virtual Reality as a tool to validate the aircraft interior with cabin attendants and passengers, has resulted in some tangible insights. It is most likely that the countertop workspace in the kitchen galley is insufficient and the screen of the self-service bar is placed too low. These insights should be included in the next iteration of the design.

8 Conclusion & discussion

Welcom
aboard

8.1 Overall conclusion

The purpose of this project was to explore the future of Onboard Services by formulating a vision for 2050 and consequently design an interior that enables an improved food and flight experience in the Flying-V.

To go beyond the theory and project domain as it is nowadays, the project is approached with a holistic view to create a viable, tangible vision on the future for all stakeholders. The passenger interaction, system integration and (indirect) stakeholder's concerns and interests have been synthesized into a new design vision.

The resulted design of the project is realised in Virtual Reality, which has also become a tool to validate the concept in another way, creating valuable new insights from a digital yet tangible perspective.

Addressing the research question

This thesis started with two research questions which were ought to be answered throughout the project.

How and to what extent is in-flight catering designed and performed in relation to its (cabin) environment?

Along the way, it became clearer how the in-flight catering industry is wired. The complexity of the domain is incredible when considering the quantities, the stakeholders and the investments that are involved in producing a simple meal. This makes it difficult to radically change, when the slightiest detail can affect the rest of the chain. Zooming in on board, also shows that the process of the meal service is a fixed procedure with little to no room for changes, resulting in an internal conflict between paying more attention to a personalised service and the efficiency of the whole service.

While the catering process on the ground as well as the service in the air are primarily fixated on efficiency, the meal itself is actually influencing the whole flight experience of a passenger. Factors such as timing, environment and service interaction contribute to the perception of the food and therefore indirectly influence the comfort peak that is caused by the food. On the contrary, food can also be perceived as overwhelming, causing a negative flight experience because there is simply too much going on: a flight attendant asking questions, a trolley blocking the aisle and a full meal tray right in front of you. It also happens when the timing is not right. Passengers do not finish or even touch their meal, causing a considerable amount of food waste.

In what way and form should the onboard services be designed in the Flying-V to deliver an improved food and flight experience with respect to the cabin environment?

As the realisation came of *why* the onboard service is as it is today, it was important to use this understanding in the design process, in order to create a viable concept. Cues for enabling an improved food experience onboard deriving from the research insights, are flexibility, interaction and digital connectivity. This was woven into a future vision statement for 2050 and a design goal for this thesis.

In the Flying-V, passengers are served custom-picked meals which can be provided at flexible times for an improved food and flight experience, in a smart and sustainable way that supports human interaction.

The outcome of the design goal is a system concept with three main aspects: an extended service experience, a digital system and a self-service bar. The different elements have been evaluated in multiple user validation tests with passengers, cabin crew and cabin designers and engineers. The overall response regarding the system from both passengers and experts is genuinely positive and rated considerably high. Their input and feedback are integrated in a concluding design, as final answer to the research question of this thesis.

This is the new LOOP: an aircraft interior system for the future onboard services in the Flying-V.

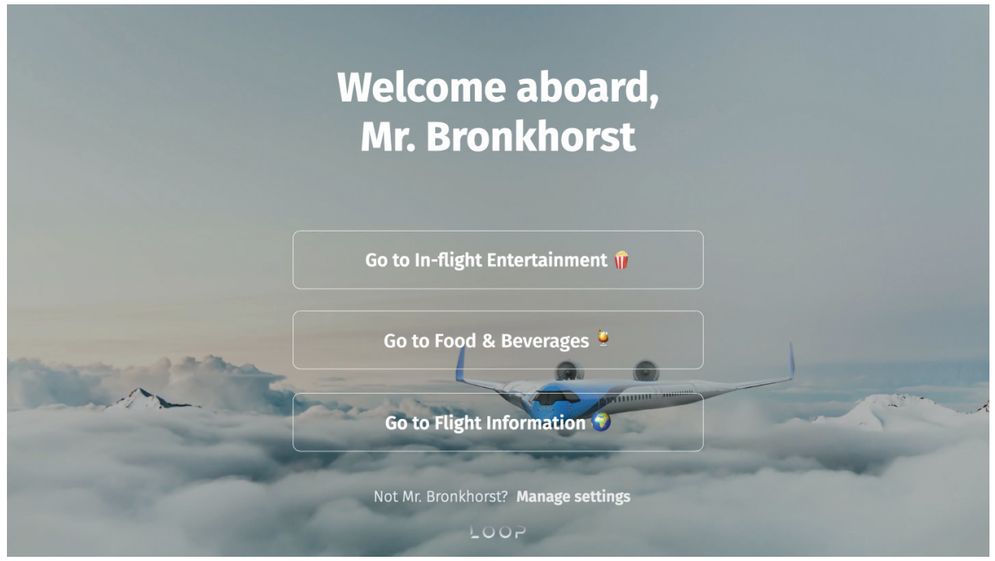


Figure 45
An example of how the **LOOP** system is integrated into the home screen of the IFE programme. The passenger can navigate to food and beverages anytime to check out the services onboard.

Select a meal round anytime

The principle of serving passengers in multiple rounds, offers them the flexibility to wait until the right moment to have a meal. The user test has shown some passengers would like to have a schedule of meal rounds from the entire flight so they know when the next round will be.

This overview of the entire flight is now added to the digital interface for the passenger. The added feature allows passengers to select a meal round anytime, so they do not have to necessary wait until the notification pops up.

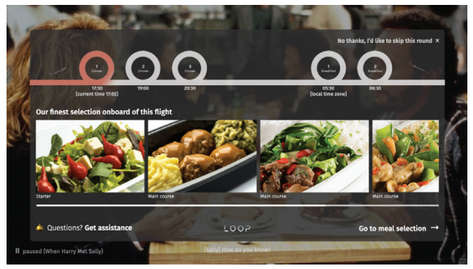


Figure 46
A timeline with meal rounds during the overall flight is added above the menu.

In contrast to the immediate course selection after a meal notification, pre-selecting a meal round beforehand does not have to include the selection of the dishes yet. Pre-selecting courses for a later meal round is only recommended when these meals are actually reserved, otherwise it might run out of stock during an earlier round, causing implications for (other) passengers. It should also be noted that the given schedule is an indication of the service timing instead of a strict timeslot, because the flexibility applies to both passenger and cabin crew side. When there are many passengers to be served in the first meal round, it should be possible to begin the second meal round a little later.

Figure 47
The dinner message bar is now the same width as the screen and the font size is increased so the text is better readible without making the interface too 'loud'. Any playing programmes continue and will be automatically pause if the message is opened.

Personal contact in each service round

While the self-service and digital system reduce the workload of the cabin crew, cabin attendants are actually concerned that this would also reduce personal contact between crew and passenger, as the validation test with cabin experts revealed. Therefore, the service of the starter and dessert is preferably not fully autonomous, but guided by the cabin attendant. It is a delicate balance between efficiency, workload and time for personal interaction and in this way, the workload of the cabin crew is still compensated with the self-driving feature of the cart, while essential human contact remains in all service rounds. As each starter and dessert round generates plentiful moments of interaction, the interaction itself can now happen in a more efficient manner because the cabin crew is aided by the self-service cart and knows which dish should be served to whom.

With the guidance of the cabin attendant, the implications for passengers in the window seat or concerns regarding passengers taking the wrong food, is also taken away.

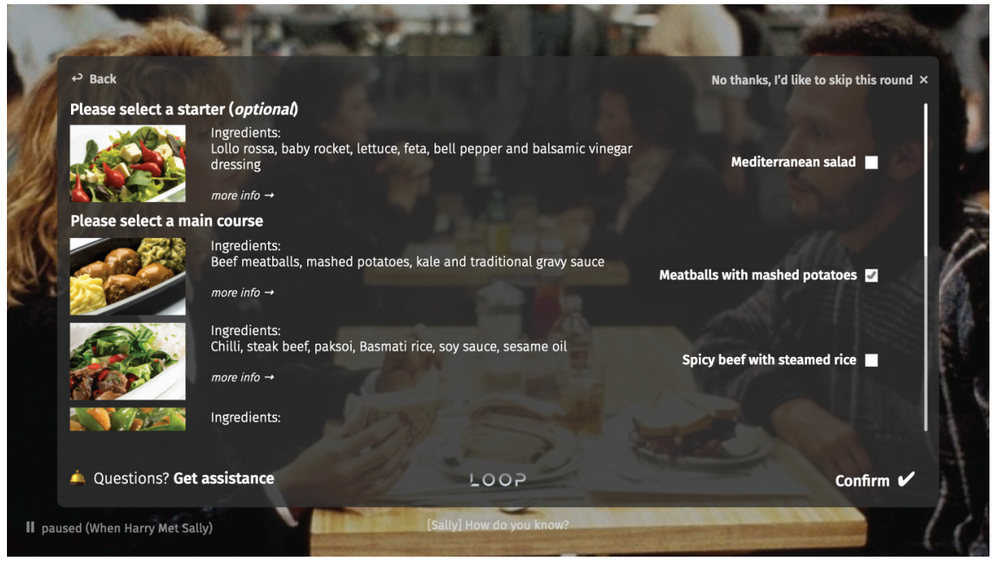


Figure 48
The renewed meal selection interface. Passengers have a better view on the whole menu and additional ingredient or allergy information and easily select their preferred dish by thicking the box.

THE PACE BAR

Passengers are welcome at the PACE BAR, a self-service galley for beverages. As validated in user tests with passengers, this gives a sense of control that contributes to the food experience. A valid concern of implementing the PACE BAR is controlling the flow of passengers and preventing it getting too busy at certain points. An indicator showing how busy it is with simple red and green lights is added to the digital interface for the passenger. This should be further tested, together with passengers on a real flight to learn how it affects the passenger experience and validate the actual effectiveness of the indicators.

Figure 49
A map of the aircraft shows the locations of the self-service bars on board and the occupation. A green light means that the galley is open and a red light means that it is too busy to visit at the moment.

The digital reminders to stay hydrated are left out of the design. The conducted user tests have shown minimal conviction that passengers will appreciate the notification and it would be a contradicting feature towards the safety concern of having overcrowded galleys.

Figure 50
The PACE BAR for passengers.

8.2 Recommendations & limitations

Naturally, every project encounters several constraints and is a final concept influenced by the specific approach of the designer. The field of OS is an incredibly large domain to say the least. With the number of stakeholders, countless details and many regulations, everything is connected as a delicate interplay. The focus of this thesis was on the conceptualisation phase of the design process, which is also an emphasized aspect of the master programme Integrated Product Design. However, considering the size and complexity of the aviation domain, a longer research phase would have been of great value for the credibility of the concept.

This concept has touched upon the key elements of the project scope but there are still some parts unexplored. This paragraph elaborates on the limitations in the process and discusses the most important recommendations for future research and development.

Limitations in the research

A deeper understanding of the in-flight catering industry could have been gained by a visit to an airline caterer. However, due to the outbreak of COVID-19, contact with KLM Catering Services has been put on hold. Therefore the analysis of the current in-flight catering process is partially based on existing videos of behind-the-scenes tours, which may be biased content. In order to increase feasibility and viability of the concept, a more extensive analysis of and collaboration with the caterer should be established in the future.

In the validation phase, the test results and gathered feedback on the passenger journey and service system were based on digital one-way questionnaires. This made it not possible to ask for further elaboration regarding the qualitative answers in the questionnaire and are therefore solely based on the interpretation of the answers by the researcher. For the same reason, the Virtual Reality sessions had an informal approach to gather input so information or insights might have been missed during the conversation with participants.

Furthermore, the participants in the validation tests are mostly from the same airline. This may be of influence due to the fact that airlines have different values set towards their OS.

The aircraft interior

In the first place, the existing layout of the whole aircraft has mostly been adopted as it is. Merely the galleys and lavatories are switched in position so the entrance of the aircraft is facing the galley instead of a lavatory. However, it could be questioned whether the lavatory and galley should be next to each other. Furthermore, the kitchen galley in area D results in an uneven layout due to the present lavatory. In addition to that, beds are next to the kitchen in the current layout. With the noise of the galley and lavatory, this might be inconvenient. This requires further research, together with the puzzle of the final seat configuration, to define the layout of the aircraft. Also, the galleys located at A and B can then be designed accordingly, which has been left out initially due to the limitations in the given 3D-model of the aircraft.

Considering all four seat concepts of the Flying-V, the designed system of the meal rounds and self-service bar may be highly suitable. The fact that passengers might swap seats by booking a bed for a few hours for instance, would mean that a flexible meal service is needed. There is more clarity and research required in the final configuration though, in order to elaborate on the service concept including the table design, timing of the meal service round in combination with any possible seat changes and the cleaning of seats and tables between swaps.

Validation with the cabin crew has pointed out that the designed countertop workspace in the kitchen galley is probably too small. For that reason, increasing the countertop workspace has been recommended as stated before. Essentially, more in-depth research is needed regarding the preparation of the service rounds and detailed scenario of it. This should also include further testing of ergonomic aspects in order to define the optimal workflow and workplace for the cabin crew.

The digital system

With the multiple choices of dishes and meal rounds, the meal selection system is highly relying on an algorithm to predict loads and efficient preparation plans. The crucial assumption that this will be feasible in 2050 is hard to validate as it considers another 30 years of development in Artificial Intelligence. To move this concept forward, it is vital to build an algorithm that is accurate and compatible with the complexity of the industry, involving different caterers, changing menus and various passengers, etc. Only with a smooth operating digital system, the concept is able to cut back food waste, catering costs and foremost, become viable in the future.

In addition, a feature to (pre-)order special meals is necessary as it may consider strict diet preferences that must not be confused with regular meals. These pre-orders are assumed to be booked in the same way as they are now (pre-flight) but can be served per course like the rest of the meal service concept. Further research is suggested in order to validate this assumption.

From a passenger's perspective, the digital meal system is foremost a digital interface like any other application. Although future passengers are most likely competent in using digital products, it is important that the meal selection is clear to first-time users. Therefore, it is recommended that LOOP is available in different languages and automatically uses the correct language by connecting to personal devices for instance. Also, the written style of the announcements plays a part in the service experience, as it symbolises a question from the cabin attendant.

The service of the meal

Due to time constraints, the autonomous cart design has been left out of the project. Although this was a sensible decision, it is recognised that its role is having a major influence on both the operational side for the cabin crew as the onboard experience for the passenger. Therefore, the following recommendations are listed to take away the assumptions that have been made in order to execute the project.

In terms of space efficiency, the autonomous carts should not come and leave the aircraft empty. Therefore, it is recommended to fill the carts with cutlery, plates for the hot main courses and/or condiments for the meal service. These need to be loaded anyway and will be handed out in the beginning. An alternative for the space efficiency may be a foldable cart that occupies minimal space when stored away or being recharged.

It is recommended that each galley is equipped with two autonomous carts with a similar capacity as conventional trolleys. In other words, with six carts in total, it would be sufficient to serve approximately 300 passengers (6x50 main courses) in one round. Considering the fact that passengers can skip meal rounds, this capacity might not be necessary. In addition to that, the courses are now served in separate rounds, so one cart can assumingly fit more than conventional meal trays. It is important to look at the handling of the hot main courses and storage, this must be designed in a way that is ergonomic for the standing cabin attendant and easy to load.

In addition to that, the autonomous cart also requires further research in autonomous driving technology. Although the technology is expected to be fully implemented in vehicles, there are different conditions on board of an aircraft. The cart also needs to be compatible with the digital system and follow calculated routes, therefore a digital screen is suggested to communicate with the cabin attendant, who can see which passenger needs to be served what and allows them also to manually control the autonomous cart through an interface.

Furthermore, the design of the cart should be both easy in recharging as cleaning. Now, the trolleys are being rinsed and desinfected as a whole. Therefore it may be recommended to make use of a detachable undercarriage that contains the self-driving technology and can be removed when being cleaned. Considering the aforementioned aspects in this context and the size of the (technical) challenge, it is suggested that the design of the cart is approached as a separate subproject.

Next to the cart, the OS also consists of cleaning rounds. Autonomous waste collection is appreciated, but further research is needed regarding the interaction between human and machine, the process and steps taken by the cabin crew and hygiene. If a similar or same autonomous undercarriage is used as the food cart for instance, what will the steps be for the cabin attendant and will this be acceptable in terms of safety and hygiene? These questions need to be answered in order to establish an inclusive service concept.

The self-service bar

Although a self-service bar has been received positively by passengers, it is acknowledged that there are still some limitations to be considered. For the prevention of overcrowded galleys and aisles, there is an indicator added to the digital passenger interface. This functionality needs to be further tested and a more extensive analysis of safety needs should be carried out to increase the credibility of self-service, including minimum number of oxygen masks and maximum number of people standing for instance.

An additional research towards the onboard offer should be conducted in order to validate a few more things: alcoholic beverages, alcohol consumption and the meal service with water.

For now, the concept has excluded alcoholic beverages from the self-service bar, so legal drinking ages will not be an issue. However, a research could also be carried out to investigate whether passengers will accept a zero alcohol beverage bar in the first place.

If alcoholic beverages are added, it would involve necessary research in load volume as well as consumption quantity. The volume of these beverages have not been included in the design and therefore needs additional space. The quantity of freely accessible alcohol might be cut back in order to prevent passengers from drinking too much alcohol. An alternative approach is to use a payment strategy, which would mean that alcoholic - or all - beverages need payment.

Moreover, the acceptance of not serving drinks or serving water only next to a meal needs to be validated with passengers. Various cultures will also look different at the meal service and have different preferences regarding food and beverages. However, it is recommended that at least water is served during the meal round when passengers are receiving their meal. With that, it is expected that the peak around meal service at the self-service bar is decreased as well. The development of clean water taps on board would be a great addition that could reduce the waste of bottles tremendously and is highly recommended to be further explored.

To check the technical validity of the design, force simulations of the dynamic components such as the fridge cassette should be performed. The materials should then be chosen accordingly that is strong enough, durable for multiple years and preferably as light as possible. This material research is also necessary for the final meal equipment such as the heat resistant plate for the main courses, the boxes for the meals and the cutlery. Reusability of the meal boxes would be a starting point for the research, as it requires a higher reinvestment in all outstations while it can also reduce a lot of waste. Best practices from Hi Fly for instance show that it is possible to fly 100% free from single-use plastics and so is the goal of the Flying-V.

8.3 Reflection

Growing up in a world where the future of the planet is debated and not knowing how much longer it can last with the continuous consumption of fossil fuels, is scary. Can it be that, one day, I will not be able to fly and visit friends and family? When I started this thesis project, I was very much attracted by the challenging attitude of the Flying-V. Justus Benad shows that challenging the conventional, can lead us to new possibilities and future opportunities. Having said that, I was thrilled to undertake this huge challenge, because it felt like being given carte blanche as a designer, which is not a daily phenomenon in the aviation industry. The Flying-V is not just a research project, it is a ticket to a cleaner, better future.

Sadly enough, climate change is not our only worry. The COVID-19 was and still is an inevitable disruption for the daily lives of all. I am grateful for the caring involvement of my supervisory board, especially during this period when it seemed that the world stood still. Not only was every meeting a positive contribution to the project results, it also gave me confidence that I was on the right track and kept me going.

My personal goal for this project was to deliver a final concept that would be truly new in the domain and significant enough to disrupt the industry. I hope that I have expressed this ambition successfully in the design of a radically different system for OS and that its core value can lead to meaningful change in the future.

One particular thing I would like to mention in this personal reflection is the lesson I learnt during this project to turn limitations into challenges. I have experienced to adapt and adjust to the situation, but also learnt to think in possibilities. For instance, I honestly did not know what to exactly expect from Virtual Reality. It was a little frightening to use this technology, because it was uncertain how my learning curve would be in the limited time left without the face-to-face help from experts at the VR Zone. The technology of Virtual Reality might have actually surprised myself the most. Once I emerged myself into a world of 'Unreal Engine', I realised the potential of using Virtual Reality in research and design. Also, I am happy to have found a way to conduct Virtual Reality tests with cabin crew at Schiphol Airport to gather feedback, despite the virus measures, something that I would not have thought of without the support of everyone around me. After this thesis, I have actually become more comfortable with stepping outside my comfort zone and to take unexpected or new initiatives to realise a project.


Welcome
aboard

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