An Investigation of Airline Catering Supply Chain Processes, Performance and Practices using SCOR Model

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Abstract

Supply chain management is critical to airlines' ability to provide high-quality in-flight dining experience to passengers. Managing airline catering supply chain can be complex and difficult because the chain frequently delivers a large volume of airline meals, manages the resulting reverse flow, and is required to meet performance requirements, often under uncertainty. This thesis delves into the business processes of airline catering supply chains, develops performance metrics for the chain, and proposes an approach for improving the chain's practice effectiveness. The thesis is divided into three main areas of study known as research projects, which are based on the portfolio of research work completed during the study.

In this thesis, the supply chain operations reference (SCOR) model is used as the reference model for airline catering supply chain. The SCOR model is generic and provides a common definition of business processes, metrics, and best practices for supply chain evaluation. The model must be adapted to fit different industry settings. SCOR-based approaches to improving airline catering supply chain effectiveness have been developed in the thesis, by selecting the appropriate supply chain processes, performance metrics, and practices that are essential to the airline catering service.

The first project adapts the SCOR model to create a framework and reference models for integrated business processes regarding the airline catering supply chain. The relevant standard processes were chosen from the SCOR model and expanded to define the specific workflow of airline catering logistics using Business Process Model and Notation (BPMN) techniques. As a result, a hierarchical process structure is defined, including how the SCOR framework's processes of source, make, and deliver map to the airline catering supply chain process. The second project is concerned with selecting performance metrics for airline catering supply chain. In adapting SCOR performance metrics for airline catering supply chains, a method of selecting performance metrics for the chain is presented. A set of 55 relevant metrics is identified from the SCOR model and prioritised using the MoSCoW based prioritisation method. Results of the prioritisation show that an emergency, such as the COVID-19 pandemic, can influence performance considerations, including the selection of appropriate performance metrics. Finally, the third project focuses on practice effectiveness. It develops a SCOR based methodology for evaluating the effectiveness of airline catering supply chain practices and identifying weak performing practices. The methodology incorporates relevant supply chain practices, practice categories, and performance attributes adapted from SCOR. The methodology uses fuzzy logic, and it is applied in this thesis to a case study of a large airline catering supply chain. The case study company is found to operate highly effective practice, and areas requiring further improvements were recommended.

The thesis demonstrates that the airline catering supply chain must pay attention to business processes, performance metric selection, and seek to continuously improve practice effectiveness. The methods and models developed in the thesis will help airline catering supply chains in all three areas. Insights from the chosen case study are valuable. Research limitations are identified, and future directions are suggested.

Declaration

I declare that the submission is my own work and that no part of this research work has not previously been submitted successfully for an award from any other university or institution.

Some components of this thesis have been published previously or accepted for publication as part of this engineering doctorate research degree programme. The publications during this study have been listed in the next section, ‘List of Publications and Membership’.

List of Publications and Membership

- Rajaratnam, D. and Sunmola, F. (2020) ‘Evaluation Metrics for Business Process Integration of Logistics Service in Sustainable Airline Catering Supply Chain’, Proceedings of the International Conference on Sustainable and Intelligent Manufacturing | RESIM 2020, p. 5.

- Rajaratnam, D. and Sunmola, F. (2020) ‘Managing Business Processes in an ERP System Context for Airline Catering Logistics’, 10th International Conference on Operations and Supply Chain Management, p. 10.

- Rajaratnam, D. and Sunmola, F. (2021) ‘Adaptations in SCOR based performance metrics of airline catering supply chain during COVID-19 pandemic’, Journal of Industrial Engineering and Management, 14(4), p. 808.

- Rajaratnam, D. and Sunmola, F. (2021) ‘Supply Chain Management in Airline Catering Service : Characteristics , Challenges and Trends’, 4th European Conference on Industrial Engineering and Operations Management.

- Rajaratnam, D. and Sunmola, F. (2022) ‘Evaluation of Airline Catering Supply Chain Practice Effectiveness using Fuzzy Logic’, International Journal of Productivity and Quality Management (Accepted/In press).

- Member of the Institution of Engineering and Technology (IET), UK.

- Member of the British Computer Society (BCS), The Chartered Institute for IT, UK.

- Member of the Operational Research Society, UK.

“Excellence is not by accident but is a continuous process.”

Dr A. P. J. Abdul Kalam

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This thesis is dedicated to my parents: my late dad Dr M.A.Rajaratnam and my mother Ishwari Rajaratnam, in honour of their sacrifices, support, and encouragement to work hard in order to achieve a higher academic qualification.

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List of Abbreviations

ACI	Aircraft Catering Instruction
ACM	Aircraft Catering Manual
AI	Artificial Intelligence
BOM	Bill of Materials
BPI	Business Process Integration
BPR	Business Process Reengineering
BPM	Business Process Management
BPMN	Business Process Modelling Notation
CAA	The Civil Aviation Authority
CPM	Catering Procedure Manual
EDI	Electronic Data Interchange
ERP	Enterprise Resource Planning
IATA	The International Air Transport Association
ICAO	The International Civil Aviation Organisation
IS	Information System
KPI	Key Performance Indicator
MRP	Materials Requirements Planning
RFID	Radio Frequency Identification
SCM	Supply Chain Management
SCOR	Supply Chain Operations Reference
TFN	Triangular Fuzzy Number
WMS	Warehouse Management System
4PL	Fourth Party Logistics

Glossary

Term	Definition
Business Process Improvement	Method for identifying and evaluating inefficiencies within an organisation to improve performance.
Business Process Integration	The synchronisation of a company's internal, external processes and information systems through the real-time connection
Empowerment	Process of becoming stronger and more confident
Logistics Execution	Perform logistical processes of a company, an integral part of the supply chain
Operations Excellence	Ability to carry out operational process more consistently and efficiently to achieve its strategic objectives
Supply Chain Agility	Supply chain’s ability in responding to marketplace changes.
Supply Chain Visibility	Ability to track products from initial shipment to final delivery through the supply chain.
Supply Chin Reliability	Ability to perform supply chain tasks as expected
Supply Chain Responsiveness	The speed at which a supply chain provides products to the customer
Supply Chain Cost	The costs associated with operating the supply chain
Supply Chain Asset Management	The effectiveness of an organisation in managing assets.

1 Introduction

The purpose of this chapter is to introduce the research carried out and investigate the airline catering supply chain. It presents the aims and objectives of the research and highlights the three projects that constitute the thesis. The remaining part of the chapter starts in Section 1.1 with the motivation for research in the airline catering supply chain, then Section 1.2 describes the thesis and ends with the thesis structure in Section 1.3.

1.1 Background and Motivation

There are several considerations of the airline catering business that motivates the research conducted in this thesis. These include the complexity of the airline business and its catering services, competitive industry forces and cost pressure, uniqueness of the business environment, and susceptibility to disasters such as the COVID-19 pandemic that cause significant disruptions. This sub section briefly introduces airline catering service and the industry, and describes the considerations that motivate the study.

1.1.1 Overview of Airline Catering Industry

Airline catering was first introduced in Europe when the regular airline passenger service was initiated in August 1919 between England and France (Jones, 2012a). Initially, their catering service consisted of only sandwiches with tea or coffee served from a vacuum flask. There was no food heating or refrigeration facilities available. Over time, In-flight meal service was developed. First, only sandwiches were served, and then the full in-flight meal service was attributed. The interior facilities of aeroplanes were considered in the aircraft design to accommodate catering functions to enhance the dining experience in the air. From a simple beverage for the economy class passenger on a short-distance domestic flight to a delicious full-course meal for the first-class passenger on a long-distance flight, airline catering industries offer a wide range of meals. There are many activities involved in presenting successful meals to the passenger in the sky. One of the critical tasks is menu planning. Several factors influence menu planning in airline catering, such as time of flight, the length of travel time, the time required to serve the food, the time needed to consume the food, cabin class, and the ability of meal to cope with low pressure and humidity and so on (Jones, 2012a).

Airline catering is a complex food service industry that provides supply and distribution services to the airline passengers. In the airline catering service market environment, these industries are not only preparing those meals, but they are also responsible for the complete airline catering solution and providing supply chain and logistics services (Gschirr, 2010). This involves managing a number of complex processes such as ordering products from the supplier, physical handling, managing inventory, distribution and final delivery of goods to the aircraft (King, 2001). Costs in the supply chain for airline catering can be reduced by using an integrated supply, production, and distribution approach. Delay, raw material purchases, material storage, and transportation are some costs that are involved in airline catering (Rezaeimanesh *et al.*, 2022).

The fundamental role of the global airline industry in the world economy is demonstrated by the fact that aviation creates 65.5 million jobs worldwide, offers $ 2.7 trillion in business activities and 35% of world trade value generated by air travel (Amankwah-Amoah, 2020). The airline catering industry is also one of the large industries in the world. The market's total size has exceeded 17.8 billion U.S. dollars in 2019 (Pulidindi and Mukherjee, 2020) and is estimated to reach around 25 billion U.S. dollars in 2026 (Mazareanu, 2020).

Airlines categorise their flight routes into three broad groups based on the distance of the flight or duration of the flight: short-haul, medium-haul and long-haul routes. Some airlines define a few other additional routes, such as domestic, regional, and ultra-long-haul. Over 90% of all routes airline passengers are covered by three major airline markets – Asia, Europe and North America (Jones, 2012a). There are many airlines in the market, including flag carriers, in Europe. Flag carriers are the airlines that are registered locally in a country. British Airways, Air France, and Lufthansa are the three top airlines that dominate the European short-haul market. However, these national flag carriers started to lose a significant amount of market share after the introduction of low-cost airlines. These low-cost airlines are changing the passengers' expectations significantly (O'Hara and Strugnell, 1997). This situation forced the national airlines to deviate from their distinctive character and implement the changes in the level of service.

The market for short-haul airlines within Europe has changed dramatically over the past decades with the introduction of several low-cost airlines challenging the status quo of carriers and changing the expectorations of passengers. Many airlines are currently offering buy-on-board meals. Airlines join with a leading retailer in the region to provide the new menu for short-haul route flights. This menu replaces the airline's complimentary meal service and includes items from the retailer food available in the economy cabin on the short-haul flight for passengers to choose and buy on board.

Passenger traffic has usually increased year on year and ready to stay in this rising trend. Despite the growth in airline passenger numbers, airline companies struggle to maintain profit margins. The airline industry has realised a continuous increase in revenue over the last decade. However, the profitability of the airline industry has been volatile upon the competition the low-cost airlines present and the rise in fuel prices.

The primary function of the airline catering business is to cater flights with an appropriate service level. This includes preparing meals, packing meals and beverages into the appropriate containers, and delivering the right airline catering equipment to the aircraft on time. To succeed in rapidly changing business environment, the airline catering operations need to be agile to handle the last-minute meal requests, special meal orders, and regular menu changes and also to be flexible in dealing with the unplanned activities such as flight schedule changes, aircraft changes, flight delays, cancellations, and other disruptions (Chang and Jones, 2007). King (2001) recognised the logistics function as the most important critical success factor in the airline catering in his research paper. He revealed two key logistics operational issues in airline catering as opposed to the ground-based catering service. They are airline catering equipment and the number of items loaded into the aircraft. However, the investigation was narrowly focused on airline equipment management and does not demonstrate other complex processes involved in airline catering logistics function.

There has been increased competition in the airline catering industry due to the advancements in the industry. Due to the cost pressure, most airlines decided to outsource their catering service. In the earlier days, the airline carriers used to operate their in-house catering service. Then they started to focus more on passenger transportation, the core business function and decided to outsource the catering service. Some catering companies subcontract the meal production and remain in the industry as the logistics service provider (Rajaratnam and Sunmola, 2020a). Outsourcing airline catering is an age-old phenomenon that has been a successful model for over three decades. But, there have been significant changes in the airline catering business over the last 15 years. Airlines were outsourcing not only the catering services but also have moved to suppliers for the entire catering supply chain and logistics services (Hovora, 2001). As outsourcing becomes a trendy option in the airline catering business, it influences logistics companies to expand their service into the new market, the airline catering supply chain. This trend enabled contract logistics providers to develop a new supply chain model for the airline business sector through collaboration with food suppliers and airlines.

Most airlines prefer to outsource airline catering services due to the availability of a diverse range of national and international cuisines and dishes, and cost-effectiveness. Strict food safety and hygiene regulations imposed by governments further increase the need for outsourcing airline catering services as it requires many certifications related to food safety. Airline catering companies are putting considerable effort into providing passengers with diverse meals, including continental dishes. The increasing passengers' consciousness of healthy and nutritious meals and the willingness of passengers to pay a fairly higher price for these meals are some of the factors influencing the growth of the meal segment. Based on the food type, the market is classified into four categories: meal, bakery and confectionery, beverage, and others. According to market research in 2018, the meal segment had the largest market share, as shown in Figure 1.1 and is projected to continue a leading position.

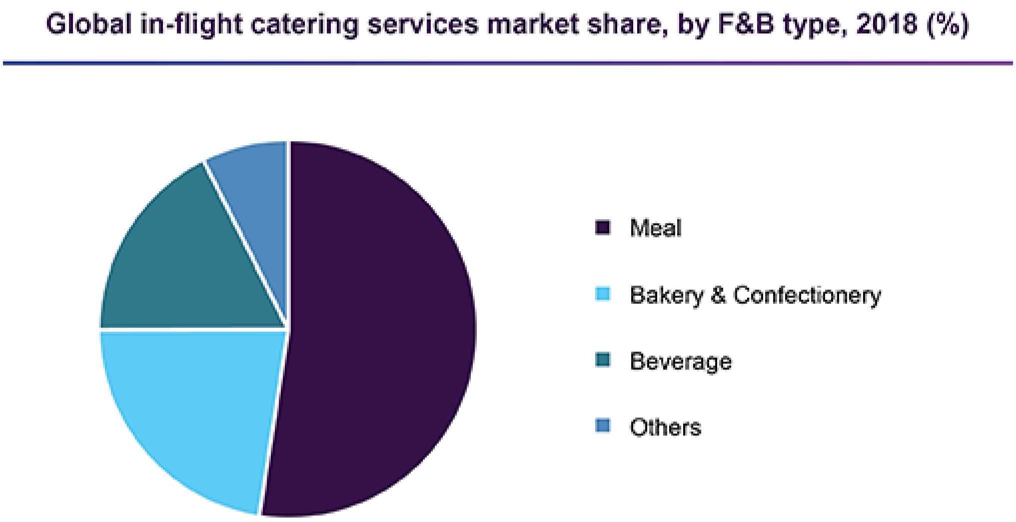


Figure 1.1 Airline Catering Services Market Share, By Food Type
(Source: www.grandviewresearch.com)

Meals on board vary in size, quality and price depending on the airline, class and duration of the flight. Airline catering organisations carefully design menus and follow the meal preparation and assembly process by incorporating food safety, aviation security measures. They prepare meals in their service centres or bring them from the kitchen to load them in aircraft galleys, and the cabin crew heat and serve these meals to the passengers. Proper attention is paid to the cooking methods to preserve the dish's aroma, colour, texture, taste, and presentation as per the meal specification.

The onboard dining experience is an essential attribute of airline passengers' satisfaction. Airlines are making a great effort to improve the quality of their in-flight food and drinks services. Airline catering organisations require to keep the meal costs as low as possible and still offer a specific product quality level. It is increasingly vital for airline catering industries to effectively manage and oversee their supply chain activities to reduce costs and enhance efficient operations. The airline catering supply chain is very complex. Therefore, there are many opportunities for improvements too. The airline catering business is rapidly evolving, and the organisations in this industry have to operate in a demanding and time-sensitive business environment (Jones, 2012b). Airline catering supply chain needs to be managed in an efficient, timely, and reliable manner to deliver the right meals, in the right quantity and the right condition, in the right catering container, to place in the right stowage position of the aircraft galley at the right time for the right flight at the right cost (Swamidass, 2000).

1.1.2 Airline Catering Service Strategy

An airline catering organisation's success depends on a steadily maintaining high quality of service within ever shorter times. Therefore, flexibility and perfection are the most critical airline catering organisations' service objectives to enhance their competitive position in this segment (Szymanski, 1995). Airline catering, being engaged in the food supply chain for ever-changing and demanding airline operations, raises this logistics position to another level. Airline catering supply chains not only have to meet the requirements for food production but also the specific conditions of airline operations, including the flight time, length of travel, class designations, destination of the flight, route sector, the aircraft type, storage limitations, serving conditions, passenger's dietary needs and preferences (Jones, 2012b). Moreover, the changes like passenger movements, flight schedule changes and aircraft changes are happening in the airline business in real-time. Therefore, catering service providers need to decide on an immediate response within a short time frame for a quicker catering service delivered to the airline. The nature of airline catering service has changed with the ever-changing nature of aircraft capacity to satisfy the requirements of carrying more passengers to the destinations. As the aircraft size and the capacity grow, the onboard galley areas become smaller (Mortensen *et al.*, 2022). An essential consideration for the airline catering product design is weight distribution to fuel ratio. In current days, onboard logistics, weight and cost determine the inflight meal concept. Airlines decide on their service strategy (Jones, 2012b). The airline catering organisation must be clear about the airline catering service strategy. These strategies depend on the time of the flight being served, duration of the flight, class designations, destination of the flight, route sector and the aircraft type. An airline catering organisation requires to keep the meal costs as low as possible and still offers a certain level of product quality.

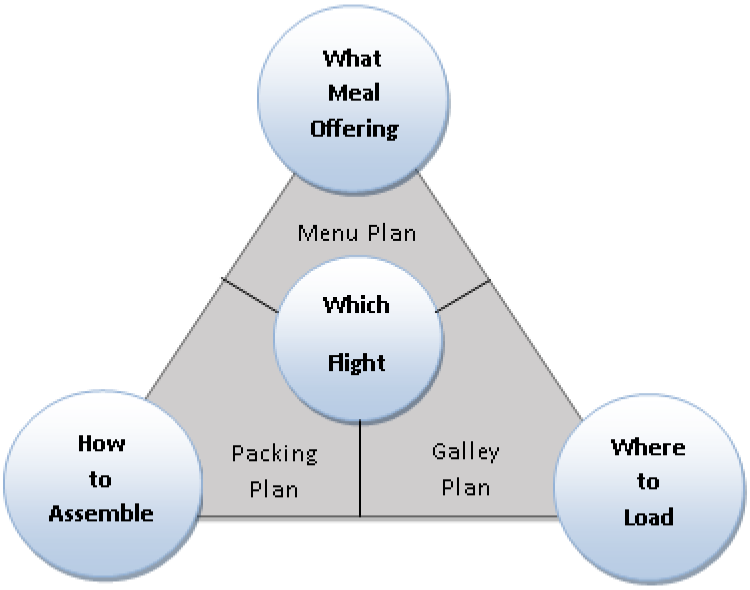


Figure 1.2 Airline catering service strategy

Figure 1.2 above illustrates the airline catering service strategy. It defines a flight's catering requirements, including meal-offering, packing information, and stowage position details. Caterers have access to the relevant guides and service documents defined by the airline. The menu plan contains information such as type of meal-offering, rules and specifications of the menu explaining the specific elements of different inflight products and services. Airlines closely work with caterers to design catering service specifications and develop menu plans. These menu plans specify what type of meal offering will be provided to different cabin class passengers on different route flights travelling at different times. The packing plan is the overall guide to the assembly activities that describe how the meals and other catering products should be packed in the catering containers. The galley plan provides the aircraft galley's layout and outlines the stowage position details that tell where to load the various catering containers in the aircraft.

1.1.3 Challenges in Airline Catering Service

Many businesses have been discovering emerging markets in the airline catering industry in recent times. This trend has influenced more and more airlines to contract the catering service out to catering companies while some airlines are still operating their own catering units. There are some challenges such as food safety, aviation security, competition, cost pressure, information technology, airline disruptions, and sustainability as they might potentially affect the airline catering industry. Reliable catering service providers take over the hassle of managing the service challenges.

Food Safety

Safety and security of the passengers are serious concerns in the airline industry. Hence, it is important to ensure the traceability of inflight products in airline catering operations. Airline catering service providers need to work in ensuring not only food safety but also the flight safety (Abdelhakim *et al.*, 2018). Food quality provision for tech crew and cabin crew, passengers and crew exposure to the undeclared allergens in onboard meals, possible risk of terrorist activities through food and water supply, and non-traceability of food waste and products in catering supply chain are some airline catering related provisions that may impact on airline operations and constitutes aviation safety (Jones, 2012a). The development of catering products is progressing so quickly, and there are also challenges in keeping the standards for food safety management that are robust enough (Asim and Yasmeen, 2021). To ensure the food safety, effective interaction between the catering service provider and cabin crew is required. The cabin crew should be aware of the type of inflight meal service and check it against the catering requirements (Grout and Speakman, 2019). The crew also needed to check the correct stowage position, with the catering container sealed and protected from any hazards such as dust, temperature, and bugs (Abdelhakim *et al.*, 2019). Airline catering service providers need to ensure that the safety protocol is considered in every stage of the supply chain process from beginning to end. It’s required to establish necessary standards for food, non-food materials procurement, goods receipt, production and assembly process, labelling activity, and despatch process.

Aviation Security

The other major issue that affects the industry is security. The evolving nature of terrorism threats and the airline industry remain to be their attractive target, enforces aviation authorities to implement more restrictions and security rules (Omweno, 2022). Airlines focus on areas like catering and ground handling and seek support from service providers for introducing best practices to drive safety and productivity improvements, and to reduce overall risks (Gillen and Morrison, 2015). Caterers may deal with airport security issues when transporting catering containers and must meet the security regulations throughout the logistics process (Jones, 2012a). This additional burden has become a challenge for catering companies whose actual priority has been food safety and the quality of delicious meals. However, it may not be too difficult for logistics service companies to comply with such security standards as they are already familiar with DFT (department for transport) operating standards and practices.

Information Technology

Information technology has been crucial in accelerating developments in the logistics sector (Antoni et al., 2020). Businesses reengineer their business processes by leveraging the capabilities of information technology to improve organisational effectiveness. The advancement in information technology has a significant impact on the airline catering industry. Information technology innovation affect airline companies both as a result of the emergence of new digital technologies on the airline catering market and when they adopt them into various aspects of their operations, such as catering production, relations with airlines and suppliers (Maiya *et al.*, 2020). Considering the review of the state of the information technology innovations and current efforts towards passenger satisfaction, it is feasible to conclude that there is room for improvement. The inflight catering services could be improved in particular by the information exchange between various stakeholders, including airlines, caterers, and airports, as well as associated processes taking place inside and outside the aircraft (Ernits *et al.*, 2022). This is also an influencing factor for outsourcing since information technology enables improved collaboration among the business partners and supports better decision-making using management information and other IS reports (Kumar and Sharma, 2021). In this regard, digitisation and information exchange are crucial as a first step for catering service optimisation, e.g., enabling customisation options for passenger meals (Georgiou *et al.*, 2010) and reducing catering waste due to over catering onboard the aircraft, as well as improving planning capacity of catering production and enhancing airline ancillary products (Ernits *et al.*, 2022). Airline companies now risk falling behind if they don't leverage the power of innovative technologies to improve their supply chain effectiveness and catering service.

Airline Disruptions

Poor weather, traffic at hub airports, and mechanical issues with aircraft are just a few of the reasons why airlines are unable to operate their flight schedules as planned. Operations abnormalities like these are referred to as disruptions (Hassan *et al.*, 2021). These events result in flight cancellations, flight delays, missed connection flights, and airport closures, affecting airlines and passengers. In the airline business, disruptions frequently occur and have a significant negative influence on operational performance. Managing these airline disruptions is another challenge in the airline catering supply chain. The operational costs of an airline could significantly rise as a result of disruptions, e.g. additional fuel usage, increased staff overtime, and re-catering service cost (Kohl *et al.*, 2007). Airline catering service providers need to support airlines in dealing with disruption events. Airline catering organisations have a significant problem as a result of shifting passenger demand for in-flight meals during disruptions (Yusriza *et al.*, 2022). To facilitate performance improvement in the airline catering supply chain, it is essential to learn lessons from historical events to deal with major disruptions due to heavy snow, volcanic ash, terrorism and security threat, and pandemic.

Cost Pressure

The development of catering services, increased passenger demand, competition between airlines (Sundarakani *et al.*, 2018), as well as the fuel price rise are causing significant cost pressure. Cost pressures are forcing airlines to reconsider their airline catering service strategy (Rosenow *et al.*, 2020). To maintain sustainable airline operations, airlines are required to manage other operational costs, such as catering service costs, more efficiently (Oktal and Oktal, 2009). Airline catering providers are under pressure to cut costs and prices. Catering providers and suppliers need to become more efficient in catering operations. Existing legacy processes and practices are one of the factors causing additional cost and complexity. Reviewing the end-to-end process and implementing the best supply chain management practices may provide the opportunity to save cost and enhance the value proposition for the customer. In addition, airlines are finding ways to mitigate the challenges of increased fuel costs and meet the increased passenger demand (Merkert and Hensher, 2011). New aircraft have been introduced to the operation with significant improvements, which adds more value to the business. These new aircraft are more fuel-efficient and more space optimised (Zuidberg, 2014).

1.1.4 Rationale of the Study

The several considerations stated earlier motivate this research study. The airlines frequently introduce a series of changes in their catering services to maintain and improve their competitive position. Therefore, catering service providers need to conduct a formal review of their catering operation, including business processes in service centres, develop new performance measures and constantly evaluate their practice effectiveness to support the airline customer in delivering their new catering service and products to the passengers effectively. As the literature shows, the biggest problem in managing the airline catering supply chain and logistics is the complexity of service and its operation. In this context, it has been difficult for researchers to apply current supply chain management models to airline catering logistics services in their current form. The operational system of airline catering service is a unique and complex concept. However, a subset of airline catering services, is better suited to have supply chain processes and practices.

This research focuses on airline catering services to identify what is essential to evaluate the effectiveness of supply chain and logistics functions in a more efficient way to meet these challenges and enhance their competitive position in today's market. This includes process design to streamline operation, develop suitable performance metrics, and evaluate supply chain practice effectiveness in airline catering service. These will result in increased customer satisfaction levels in which airlines are always highly sensitive (Hovora, 2001) and the overall best result for a company in the airline catering business. This research seeks to investigate the airline catering supply chain industry by studying one of the UK's leading organisations in the industry.

1.2 About the Thesis

This thesis attempts to address some of the challenges arising from considerations discussed in section 1.1. The research study explores the business processes, performance considerations, and best practices within an airline catering enterprise and develops solution approaches for internal supply chain process modelling and performance measurements that enhance airline catering logistics service effectiveness and related supply chain improvement activities. The primary purpose of this study is to demonstrate that a supply chain reference model can be used with little adaptation in the airline catering industry. The model would be suitable for airline catering services that are highly standardised and repeatable and demonstrate supply chain management function characteristics.

This research incorporates the present state of academic knowledge about the SCOR model and the best business practices from the airline catering industry. The purpose of this study is to investigate the nature of airline catering operations, review the processes in the airline catering supply chain to design business process models, understand performance considerations to propose suitable performance metrics and explore the supply chain practices in the airline catering business and to develop an approach for evaluating practice effectiveness.

An established framework, the SCOR model, was chosen to develop a reference business process model that forms the basis of supply chain process modelling for airline catering organisations. The SCOR is a reference model used in supply chain management. It provides tools and methodology for organisations to manage their supply chain more efficiently and effectively. A more detailed overview of the SCOR model is contained in Section 3.1. The relevant supply chain management activities necessary for the business process model have been identified by interviewing experts and using literature review, and other primary and secondary sources. The research study revealed that the modelling and optimisation of processes are still in their early stages at airline catering organisations. This framework is intended to link the operational language and discipline of airline catering with the modelling language and principles of information systems engineering. This framework can describe the complex supply chain processes of the airline catering business and support the organisation in modelling and streamlining its supply chain processes. The standardisation of airline catering supply chain processes and business process integration is encouraged in this research which is critical to improving catering service efficiency and supply chain effectiveness as well as the better coordination with external stakeholders such as airlines and food, non-food suppliers in airline catering operations. This research is based on a single case study and provides the basis for further research on business process management, process modelling and optimisations in the airline catering supply chain.

The result of adapting the SCOR model to the airline catering business sector environment is called as the Airline Catering SCOR model (ACSCOR). The ACSCOR model holds the basic structure of the SCOR framework and maintains processes and performance metrics in the SCOR model's original state. ACSCOR model can be used by airline catering service providers. To be specific, the ACSCOR model is a "complement" to the SCOR model with adapted industry-specific processes and selected performance metrics. In such manner, airline catering organisations can exploit the SCOR framework and the ACSCOR model to map the airline catering supply chain from food, non-food suppliers to the service centre and from the service centre to the airlines.

This research study attempts to design supply chain processes, to develop performance metrics, and to evaluate practice effectiveness for the airline catering supply chain based on SCOR model concepts. The research engages in an investigative study to analyse the current airline catering supply chain processes, practices, and performance measures with a focus on adapting SCOR reference model.

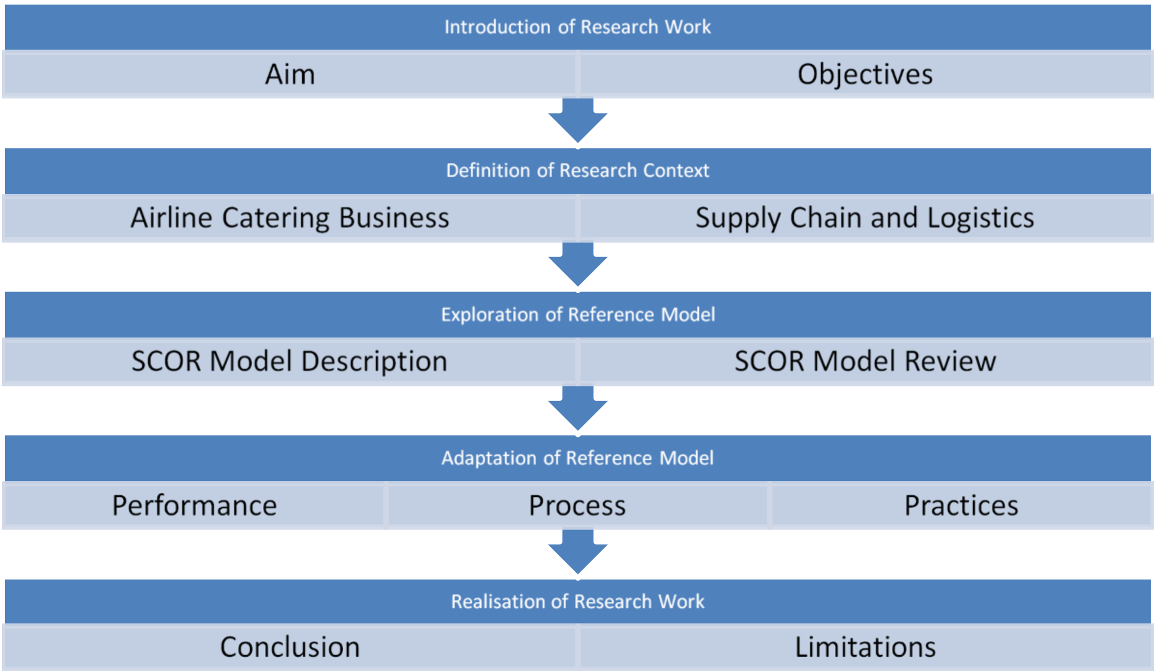


Figure 1.3 Research Overview

Figure 1.3 is an overview of the research and shows how various phases of this research fit together and set out different research work and associated three key areas of the research focus: Process, Performance and Practices.

1.2.1 Research Aim and Objectives

The current industrial issues have exposed the need for a research study into airline catering supply chain efficiency that incorporates the present state of academic knowledge about SCOR and the best business practices from the airline catering industry. Hence, the aims of this research are to investigate the business processes of the airline catering supply chain and develop an approach for evaluating airline catering supply chain practice effectiveness based on performance considerations. This research uses the SCOR reference model to link performance metrics, processes and practices into an integrated structure for the airline catering supply chain. To address this research aim, a key research question that should be considered in this research. The question is "How can the SCOR model be adapted and applied to the airline catering service for improving its supply chain effectiveness".

The objectives of this research are to:

1. Explain the airline catering supply chain landscape, the opportunities, and challenges it presents.

2. Design a business process architecture for airline catering logistics based on the SCOR model, and identify the underlying processes and associated process maps.

3. Establish SCOR based performance metrics relevant to the airline catering supply chain.

4. Examine the influence of uncertainties as presented by the COVID-19 pandemic on the prioritisation of SCOR based performance metrics in airline catering logistics and discuss the key considerations.

5. Develop an approach for assessing airline catering supply chain practice effectiveness and for identifying areas requiring improvement.

1.2.2 Projects covered in the Thesis

The typical feature of the engineering doctorate (EngD) study at the University of Hertfordshire is based on a portfolio of research work. This approach replaces the single topic focus research and includes multiple projects. This thesis is made up of three projects shown in Figure 1.4. This thesis investigates and recommends procedures to improve airline catering logistics service and its supply chain operations capabilities. Following the careful review of supply chain performance measures in previous literature, it was decided to use the SCOR framework in conjunction with the airline catering supply chain principles to improve the airline catering organisations' supply chain performance and the effectiveness of their catering operations. The SCOR model version 12 has been adapted to model the supply chain processes of the airline catering business. This research is one of the few studies that are being worked on the implementation of the SCOR model for the airline catering supply chain, an emerging and important research area in the travel, tourism, and aviation industry.

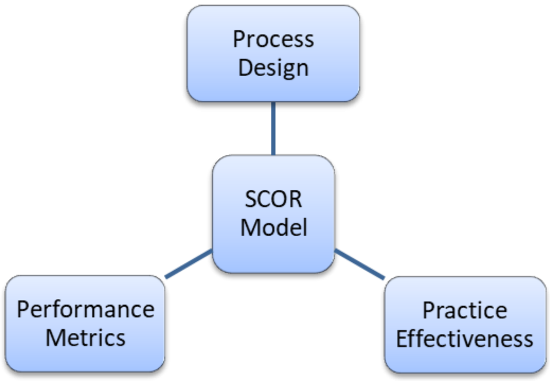


Figure 1.4 Thesis Projects

To define the work within this research, this thesis is divided into three projects. They all are based on the SCOR model, as shown in Figure 1.4 above. First, it analyses in detail airline catering organisation's current logistics and supply chain processes, coordination methods and understanding the process design that can support the integration of compartmentalised business processes into a synchronised logistics execution. It produces a part of the thesis for a blueprint to implement integrated logistics functionalities in airline catering service to manage its increasingly complex logistics operations. Then it describes the performance metrics development approach and explains how it was developed using the SCOR model and how it was prioritised to apply for performance consideration changes during uncertain times. Following the performance metrics development, the thesis presents the practice effectiveness evaluation model and gives guidance on how airline catering organisations can use the evaluation model to assess their supply chain practice effectiveness.

Process Modelling

The need for a business process design framework is apparent for airline catering organisations that focus on logistics and supply chain processes for efficient catering service. This research project aims to develop and apply a business process design approach that supports business process integration in the airline catering supply chain. This project presents a case study of developing a business process modelling framework based on the SCOR model and the approach for supply chain process modelling adapted to the needs of airline catering organisations. The case study was carried out to identify and analyse the airline catering organisation's current supply chain and logistics processes. Business process models representing airline catering logistics execution activities are created. The viability of the developed process models is validated by experts, and the applicability of the proposed business process design framework is demonstrated through the case study.

Performance Metrics Development

There is the propensity of airline catering supply chains to adapt their performance measures in order to meet desired service levels due to the challenges of the COVID-19 pandemic. The aim of this project is to develop a set of metrics for airline catering organisations and explore the choices of SCOR based performance metrics during the COVID-19 pandemic. A case study approach involving an airline catering supply chain organisation is adopted in this research. The SCOR framework is applied in the context of the case study supply chain to develop a performance metrics model for the chain. The performance metrics model is analysed and validated by a set of experts in the case study organisation. A hierarchical performance measure framework is proposed, and a set of 55 metrics from the SCOR framework is identified and validated for airline catering supply chains.

Practice Effectiveness Assessment

There is a strong relationship between supply chain practices and supply chain performance. Many organisations have realised significant benefits after implementing the best supply chain practices. This project aims to present a conceptual model and approach for evaluating the effectiveness of supply chain practices in the airline catering business. The research study of this project demonstrates the development process of an evaluation model to assess the effectiveness of supply chain practices in the context of the airline catering business using fuzzy logic. The model was developed from 5 performance attributes, 13 practice categories and 39 supply chain practices identified from the SCOR framework and the best practices currently being adopted in an airline catering organisation.

1.2.3 Contributions of the Thesis

There are some main contributions to the knowledge and practices from this thesis.

1. The work done in this thesis has contributed to the recognition of current challenges in the airline catering supply chain and reinforced the positioning of the SCOR as the reference model for addressing the identified challenges in the airline catering supply chain.

2. This thesis has designed a SCOR based reference model and business process models to support business process integration for airline catering logistics execution.

3. It developed a set of suitable performance metrics based on the SCOR framework for the airline catering supply chain.

4. This thesis demonstrates the need for adapting the choices of performance metrics when face with disruptions such as those arising from the COVID-19 pandemic and presents a validated approach for carrying out the adaptation.
5. Prior to this thesis, there has been an unfulfilled industry need regarding how to assess the effectiveness of airline catering supply chain practices, and this thesis has developed a method for the assessment.
6. To support the realisation of the benefits of carrying out airline catering supply chain practice effectiveness assessment, this thesis put forward an approach for identifying areas that airline catering supply chain should recognise as necessary to focus on in their continuous performance improvement programmes.

These contributions have been validated using real industry case study. The organisation that participated in this case study is described below.

1.2.4 Case Study Organisation

This research conducted a case study in the airline catering organisation in the UK referred to as Company X. It offers a variety of services from procurement, product sourcing, tray and trolley assembly, food and beverage replenishment and final distribution to aircraft as well as a full wash up service of airline catering equipment. Company X is a leading logistics and supply chain company that initially entered the airline catering business with the primary aim of offering logistics services by working with food partners. The company brought their knowledge and expertise from logistics business experience. It has good insight into the current state of business functions and practices such as reverse logistics, sustainability support, reducing waste and flexible catering operation in the airline catering business. Developments in later years to fulfil the organisation's vision of being a one-stop shop for its customers, it further extended its supply chain service in airline catering by bringing the food assembly operation in-house along with its warehouse operation combined with a broad range of additional value-added services. This integration enabled the catering organisation to play the roles of both caterer and distributor in this business. At the same time, it leads to a position where it needs to provide complete airline business solutions and manage the entire supply chain and logistics processes for airline catering services.

Company X offers a new approach to airline catering service by providing end-to-end airline business solutions through its service centres. The service centre is essentially a distribution centre within the airline catering supply chain industry sector whereby company X exploiting its supply chain expertise, has constructed an effective supply chain for the airline customers from raw material procurement to final delivery of finished products to the aircraft. It provides catering and catering handling services to different airline customers with an operation of 300 flights a day through different service centres. The company has an engaging work relationship with many suppliers to find the right products, both customer-nominated and sourced products, to meet customer expectations. The materials are brought into the service centre, and its operations provide further value-added services to enhance the experience of the customer and put together as a shipment for each of the aircraft. This end-to-end supply chain performance is achieved through a combination of technology solutions and manual effort. As part of the innovative solution brought to this airline catering supply chain industry, the use of barcode technology was introduced to the food service sector. All the goods entering and exiting the site would be recorded via scanning or data entry with the help of portable handheld scanners to maintain correct inventory, provide the customer with full visibility of their assets, and help with inventory management. There are several industry-specific software solutions with a broad functional scope developed by today's market leaders of enterprise software applications. It replaces the one-size-fits-all concept with one tailored to a particular industry's needs. Currently, there is no such single integrated industry-specific solution available for the airline catering business at company X. The primary supply chain software systems available at company X today are not linked together in a meaningful way and deal with some specific business requirements of the airline catering supply chain ineffectively.

1.3 Structure of the Thesis

This thesis is divided into eight chapters. The first chapter, Introduction, provides background information about the airline catering supply chain to contextualise the research study. It highlights the complexity and challenges in the field and describes the motivation for investigating the supply chain's performance considerations and practice effectiveness in the context of airline catering. Further, it defines the focus of the study by specifying the project's overall aim and research objectives. Then it briefly explains the projects covered in this research and the structure of the thesis is outlined.

Chapter two characterises the airline catering supply chain. An introduction to the airline catering supply chain, the structure of the chain, supply chain stakeholders and their responsibilities are stated. This chapter also explains the supply chain operations and outsourcing practices in the airline catering industry. Additionally, it discusses the airline catering supply chain practice and performance requirements and describes the sustainability needs in the airline catering supply chain.

Chapter three of this thesis presents the selective literature to understand the topic and to critically review the SCOR based research works done by other researchers. This chapter also establishes the similar or related work in supply chain management and demonstrates how this research program fits into the general framework within three main themes that this thesis links, namely the business process management, the development of performance metrics and prioritisation, as well as measuring the supply chain practice effectiveness from the perspective of supply chain's performance importance.

Chapter four explains the methodological approach used in this research to complete the research objectives and achieve the overall aim. The research methodology chapter discusses the research philosophy, describes the research process, and justifies the chosen research methods. Further, the data collection methods are covered, and data analysis is discussed in this chapter.

Chapter five defines the process design approach to support business process integration of airline catering logistics function. It clarifies the requirements for business process integration and develops a reference model based on the SCOR framework. In addition, this chapter provides the process architecture and mapping along with industry-specific business process models.

Chapter six focuses on the adaptation and development of performance metrics for the airline catering supply chain. It defines the approach, including the case study method adopted in this project. It also describes the prioritisation technique for the choices of metrics for performance measures during uncertain times. Lastly, this chapter provides the case study results and discusses the findings.

Chapter seven describes the supply chain practice effectiveness evaluation approach based on fuzzy logic. It presents the evaluation approach and design of the conceptual model for practice effectiveness assessment in the airline catering supply chain. Moreover, it demonstrates the application of the evaluation method in a case study and discusses the case study results.

Chapter eight summarises the conclusion arising from the results of three projects covered in this research. This chapter discusses the applicability of research findings and contributions of three projects to underscore the academic and professional value of the research. It further considers the study's limitations and provides recommendations and directions for future work.

2 Airline Catering Supply Chain

2.1 Introduction

Supply chain management and logistics play an essential role in the airline catering business. The airlines' cost reduction strategies have recently shifted the focus from culinary aspects to supply chain management (Whyte and Lohmann, 2020). Airline catering service providers need to be effective and innovative in their catering services to maintain and improve their competitive position. The effectiveness and efficiency of the supply chain process in airline catering have been proven to increase with digital advancement (Yusriza, 2022). However, digitalisation in airline catering is a topic that is rarely covered and explored in research. The level of development in the airline catering supply chain can facilitate or constrain the economic performance of the airline industry. Therefore, various aspects of the airline catering supply chain need to be explored in the growing market with its own distinctiveness.

The purpose of the research presented in this chapter is to identify the distinct characteristics of supply chain management in the airline catering industry. This chapter examines the competitive nature of the industry, the airline catering supply chain, its structure, and operations, as well as concepts, issues, and future directions. Furthermore, the findings from the case study presented as examples in this chapter are used to uncover additional facts and contribute to the existing body of knowledge. The chapter concludes with a discussion of the outsourcing business practise and the sustainability requirements in the airline catering supply chain.

2.2 Airline Catering Industry

The airline catering industry is distinguished by a high level of customer service focus and, at the same time, by a high level of ambiguity and volatility regarding consumer demand and aircraft passenger counts until just before take-off. These factors prevent effective service delivery and necessitate constant responsiveness throughout the supply chain (Brinkmann and Klug, 2020). Industry structure and competition are a few key issues that might affect the airline catering industry, with other operational challenges mentioned in Chapter 1 (Jones, 2012a). The competitiveness of the airline catering business environment has been examined by applying Porter's five forces model. Porter's Five Forces model is a tool for analysing the industry environment and its competitiveness (Mukhezakule and Tefera, 2019). A previous analysis of Porter's Five Forces revealed that airline companies were among the least profitable industries due to the intense competition (Kankaew, 2022). The summary of analysis findings related to the airline catering industry is listed in Table 2.1 below.

Table 2.1 Porter's five forces in airline catering industry

Force	Power
Threat of New Entry	Low
Rivalry	High
Threat of Substitution	Low
Power of Suppliers	Low
Power of Customers	High

Threat of New Entrants

The threat from new entrants is low as companies need significant financial investment to establish themselves in the airline catering market. Raising entry barriers will make it more difficult for new businesses to enter the market, reducing the risk of new competitors (Wood *et al.*, 2021). One important strategy used by dominating food companies to expand and conquer new markets is the acquisition of food manufacturing businesses (Baker and Friel, 2016). Major food corporations have primarily entered emerging markets through mergers and acquisitions. These tactics are frequently implemented in the food business (OECD, 2014). However, high market saturation is another factor that prevents companies from entering the airline catering business (King, 2001). The company's location is an issue as flight kitchens and assembly centres need to be located near the airports. Finding a premium location in such a popular area is difficult, and the cost of the space will also be high (Jones, 2007). For newcomers, it's becoming more and more challenging to achieve cost advantages and compete with large catering companies in this industry where fewer parties control the airline catering supply chain. All these barriers can lower the threat of entry.

Rivalry Among Competitors

The competition between businesses in each industry typically manifests as jockeying for positions. High levels of rivalry amongst current competitors in a market can influence the level of profitability generated in the market (Baxter, 2019). A variety of factors, such as the industry growth rate, fixed/storage costs, the balance of competing businesses, switching costs between competitors, differentiation, or obstacles to market departure, might have an impact on this force (Porter, 2008). The airline catering market is very competitive since many large and well-known catering service providers operate in the airline catering business sector. The main competitors compete over gourmet menu designs, catering costs, quality standards, and service performance to remain competitive in the market and to attract new airline customers (Sundarakani *et al.*, 2018). The cost of building, equipment, and aircraft catering trucks for providing catering services is high in this industry. And finally, increased financial penalties or losses may occur as a result of ceasing catering services. Although the airline catering industry's growth is fast (Department for Transport, 2018), other factors mentioned here, are making competition more intense.

Threat of Substitute Products or Services

A substitute threat is a risk brought on by substitute items. Porter claims that it's critical to determine whether other production firms' goods can fulfil the same purpose as a manufacturer's original goods (Porter, 1991). Depending on the respective price-to-performance ratios of the many goods or services that customers can use to meet the same fundamental need, alternative items can threaten the profitability of an industry (Yunna and Yisheng, 2014). Substitute products are more competitive when the price is lower, or the quality is higher. This is not the case in the airline catering industry and the threat of substitution is low. Inflight catering services impact overall passengers' travel experience, and there is no direct substitute for inflight meals (King, 2001). The low-cost carriers and a few other large airlines have stopped their complimentary meals and snacks service onboard for economy class passengers in short-haul operations. Some alternatives such as buy-on-board meals and pre-order meals have now been introduced instead (Jones, 2012b). Though these alternative services may impact traditional airline catering, they do not pose any serious threat to airline catering companies' sustainability (Whyte and Lohmann, 2020).

Bargaining Power of Buyers

Powerful buyers can increase value by driving down prices and pitting incumbents against one another (Jones, 2013). Therefore, influential buyers have the potential to reduce the industry's profitability. If customers have a lot of purchasing power, and they are small in number, they may quickly transfer suppliers. The majority of these sources of purchasing power can be attributed to both individual consumers, and business and industrial buyers (Porter, 2004). The bargaining power of the buyers is relatively high in the airline catering industry since buyers are more concentrated than sellers (King, 2001). There are few airlines and many caterers within a region. Airlines are price sensitive and are well-educated regarding inflight products and catering services (Khudhair *et al.*, 2019). Airlines face cost-cutting, and their profit margin is low. Hence there's pressure for low costs (Eksi *et al.*, 2012). Airlines have their own experts working with catering companies to design menu plans and meal specifications. They have more influence in the development of catering services. Also, Airlines purchase a high volume of meals (Mitro, 1998). Additionally, In the airline catering service, the quality of the meal is paramount. The inflight catering service will have an impact on the airline's prestige and passengers' experience (Eksi *et al.*, 2012). All the above factors indicate that airline customers' power is high.

Bargaining Power of Suppliers

Suppliers can use their negotiating position to increase prices or lower the quality of the goods and services they offer, which they can use to pressure incumbents in the market. Therefore, strong suppliers can force profitability out of a sector that struggles to recoup cost increases at its own rates (Kabeyi, 2018). Customers have the power to influence pricing, demand higher quality or better service, and play rivals against one another (Baxter, 2019). Airline catering companies purchase food and non-food items from multiple suppliers. They have an engaging relationship with the local network of suppliers, often calling tenders and negotiating a lower price based on large volume purchases for their airline catering production (Lin, 2018). Most of the food, and non-food items that caterers purchase are undifferentiated, and substitutes are readily available for them in the market. Caterers can select suppliers who provide high-quality products for a low price (Fu, 2019). Catering companies have clear legal clauses against supplier delays. They put high emphasis on punctuality in their contract with suppliers and will charge penalties for late deliveries and also reserve the privilege to find an alternative supplier in the event of delivery failures (Lin, 2018). Therefore, the bargaining power of suppliers is relatively low in the airline catering industry due to these factors.

According to Michael Porter's five forces of competitive position analysis, an industry is attractive when the power of all the forces is low collectively (Rajaratnam and Sunmola, 2021a). As per the above aspects of the industry's competitive structure, we can conclude that the airline catering industry shows some attractiveness. There are some opportunities for better performance in this sector. Figure 2.1 presents a graphical illustration of the characteristics of competitive forces in the airline catering industry.

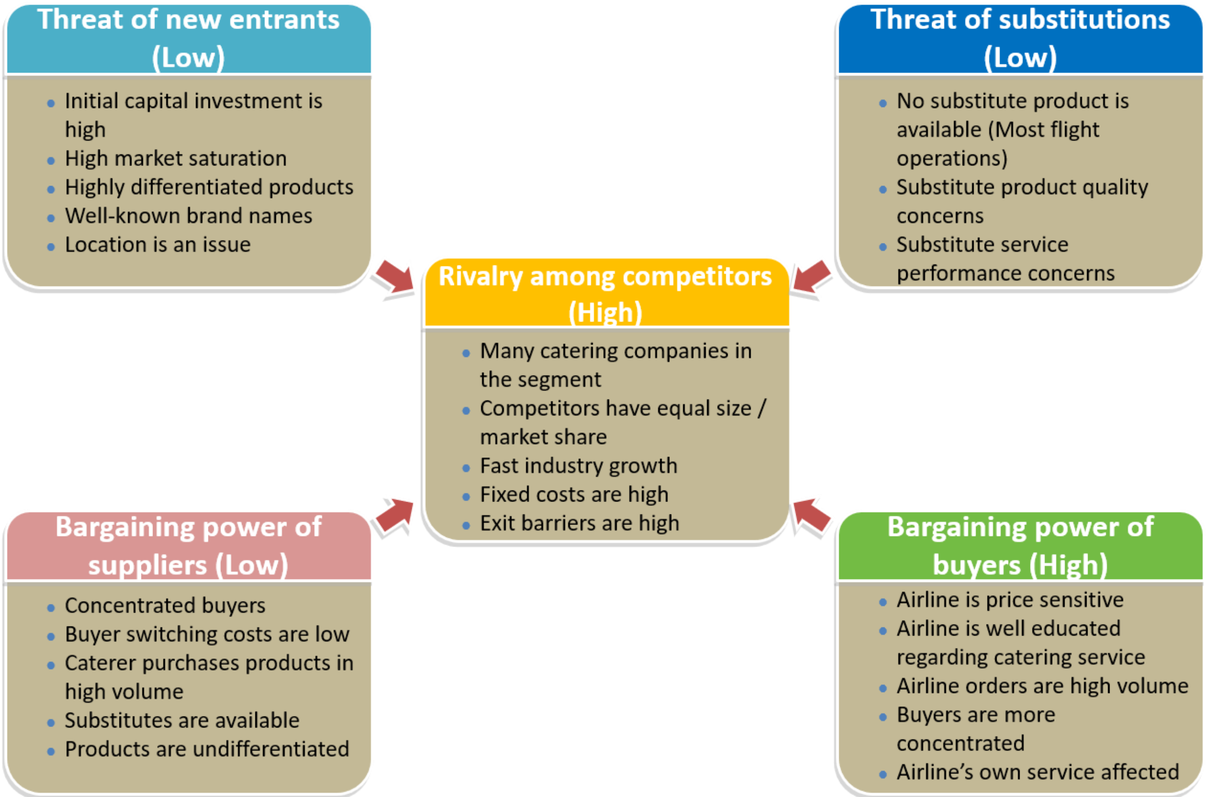


Figure 2.1 Porter's five forces analysis for the airline catering industry

2.3 Organisation of Airline Catering Supply Chain

For many businesses, the supply chain is an essential component of their operations. The best supply chains are not only efficient but also effective (Baah, Acquah, *et al.*, 2022). Efficient supply chains make the best use of their resources, which include financial, human capital, technology, and materials (Alshurideh *et al.*, 2022). This reduces processing time, lowers overall operating costs, and improves quality. This enables businesses to provide their customers with faster, cheaper, and better products and services (Wang *et al.*, 2020). When a supply chain meets the needs of its stakeholders, it is considered effective.

Effective and efficient supply chain management is critical to airlines' ability to provide high-quality dining experiences to their passengers (Sundarakani *et al.*, 2018). However, managing the large volume of meals from the kitchen to the aircraft, as well as the reverse flow of equipment and unused items, has always been difficult for airline catering companies in a very complex environment (Kumar *et al.*, 2015). They appear to be inefficient and uneconomical in general. In addition to this challenge, the airline catering industry is constantly confronted with increasingly volatile customer demand (Gschirr, 2010). In comparison to other industries, prompt response to frequent changes in business requirements is critical in airline catering (Yusriza *et al.*, 2022). Changes in airline catering requirements will continue, and the rate at which airlines issue airline catering instructions to make these changes is only likely to accelerate.

Executing the airline catering supply chain is possibly a convoluted task. Each flight is loaded with a variety of materials, including meals, beverages, toiletries, and earphones. Thousands of items must be loaded into a larger plane, such as an A380 or a 787 (Hovora, 2001). This includes managing complex processes like ordering products from suppliers, physical handling, inventory management, distribution, and final delivery of goods to aircraft (Jones, 2007). The meal on board may appear to be prepared by a lone entity (the airline). This isn't as simple as it appears; it's the result of much more widespread interactions between multiple stakeholders in the airline catering supply chains, including governments, airlines, logistics service providers, caterers, meal suppliers, and passengers (Park *et al.*, 2020). Such intricate coordination demonstrates the complexities of operations in the airline catering sector, where organisational principles like outsourcing, vertical integration, and just-in-time assembly are equally important (Primo *et al.*, 2021).

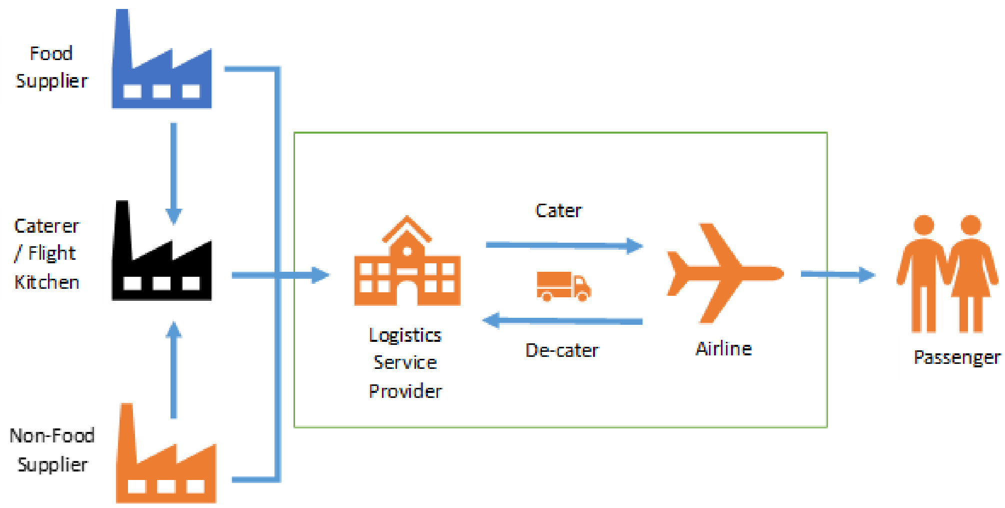


Figure 2.2 Airline Catering Supply Chain

The airline catering supply chain is typically made up of five major parties: the airline, the caterer, the supplier, the logistics provider, and the passengers. Figure 2.2 depicts the typical supply chain structure and relationships between parties in the airline catering supply chain. The airline industry is becoming increasingly competitive. Most airlines are attempting to save money by taking advantage of opportunities in the airline catering supply chain (Lin, 2018). The total cost of ownership in the supply chain is the responsibility of each organisation. Each stakeholder works together to achieve cost efficiency. Each stakeholder in the supply chain is responsible for something specific. Airlines are in charge of designing in-flight services such as menus and onboard logistics. Caterers are in charge of preparing meals as well as assembling tray sets and airline catering trolleys. Though most meals are prepared fresh, caterers also use frozen meals for economy cabin classes. It offers significant cost savings because it is less expensive than freshly cooked meals and produces less waste (Halizahari *et al.*, 2021). Suppliers provide all materials, such as ancillaries, tray set components, and snack items, in accordance with the menu profile specifications. Some are nominated by airline customers, while others may be chosen by caterers. Logistics providers are critical components of this supply chain. They manage all airline equipment, including consumable and rotable items. They are responsible for transporting meals, bars, and equipment from the kitchen or service centres to the aircraft and loading them. They also return them to the facility from returned flights (van der Walt and Bean, 2022). Logistics service providers in the airline catering supply chain are typically world-class logistics companies that specialise in goods movement and storage. Catering logistics providers for airlines are solely responsible for the overall logistics processes and catering service quality. They manage the majority of the airlines' supply chain. They provide solutions in the areas of planning and design, purchasing and delivery management, assembly operations, airport operations, last-mile delivery, and return management.

2.4 Airline Catering Supply Chain Operations

The airline catering supply chain is one of the world's most complex operations systems. Jones (2007) recognised the system's complex features by relating each element to other distinct operational environments. He compared the method of serving meals to onboard passengers to a restaurant, the food preparation method to a manufacturing plant, food and equipment storage to a freight warehouse, and catering consignment transportation to military-style logistics.

An excellent service experience is the foundation of a great customer experience. According to service level expectations, airline catering service providers plan not only the menu but also the in-flight product and all the services required to deliver passengers onboard and delight them (Mahmoud and Rady, 2020). To provide the catering service, the airline catering service consists of operating functions such as meal assembly, tray sets, and catering containers as per the daily flight schedule. The critical distinction between operating and catering functions is due to the fact that each individual food item is produced elsewhere, outsourced from the food supplier, and only brought into the service centre to assemble meal trays and containers, whereas the operating functions are handled in-house.

Airlines review their existing catering products for the various cabin classes on a regular basis and make any necessary changes. Changes to meal offerings, changes to airline catering equipment, new menu profiles, new route classification, new galley plans, and stowage manuals are examples of these. Flight operations are classified into three types based on their travel distance: short-haul, mid-haul, and long-haul (Klophaus and Yu, 2023). Route groups are further classified for each flight operation. Airlines may rearrange their route groups within their flight operations, creating new route groups or moving certain destinations to different groups based on the amount of time spent flying. These route groups cover multiple destinations and have varying levels of catering service. Some airlines only offer one class of service on domestic flights: economy. Some domestic airlines are introducing business class and offering high-quality meal service. These changes necessitate that caterers adhere to the new onboard logistics plan documents, galley plans, and aircraft stowage manuals. These documents describe how to load food, equipment, and bar supplies onto aircraft.

In airline catering operations, it is critical to consider the influencing factors that define and distinguish the galley planning information. Airlines provide a variety of food and beverage options for passengers to eat and drink while travelling, depending on factors such as flying class, distance travelled, and service type (Ernits *et al.*, 2022). The meal offering of the flight is determined by key factors such as the flight travel time to the destination, which is assigned to the flight route category, and the outbound and inbound departure schedule. In addition to these considerations, the flight departure date influences the onboard meal loading plans. Loading procedures will differ depending on whether the inbound sector flight returns the same day or a night-stopping flight returns the next day. Night-stopping flights require special chilled box equipment to maintain food quality and safety. As a result, even though the meals are the same, the galley stowage plans differ between the same-day flight and the night-stopping flight.

Each aircraft has a galley where the in-flight catering products are kept. Each of these galleys has several stowage positions, and each stowage position can hold one or more catering containers (Mortensen *et al.*, 2022). As per the catering requirements, each container will contain different contents in varying quantities. Catering equipment such as trolleys, boxes, insulated boxes, and oven racks are examples of these containers. On different days, different aircraft types may be scheduled for the same flight, and the same flight may also depart at a different time. For example, flight XXX will leave at 8:00 a.m.

during the week and 10:30 a.m. on weekends. As a result, it is common for separate galley plans to be generated for different aspects of catering provision, such as the flight's destination, aircraft type, outbound and inbound flight departure times, and inbound flight departure day.

It is difficult to directly transfer aircraft galley planning data from the airline's information system to the caterer's systems when there is no interface between the two systems and the working principles of the functional modules in both systems are different. Airlines publish their onboard logistics planning information in a standard format, but it is too diverse. While caterers must cater to many flights linked with various aircraft types in a single day, there is no easy way for caterers to correlate the correct galley plans to the correct flights in daily operations. This is an important process step for the caterer's supply chain systems to generate order requirements and find inventory for airline orders. Caterers must assign the correct galley plan to airline orders for various aircraft types and destination flights with varying departure times. They must perform the majority of their adaptations on their own, utilising their information system. Business processes in the airline sector are never static. They are constantly changing. Airlines frequently believe that their catering service could be improved and, as a result, make changes (Kwon *et al.*, 2021). Catering service providers must be able to configure existing system functionalities and create new solutions. To address the galley plan allocation challenges, they need to implement appropriate functionalities with related system configurations in their information systems. The suitable customisation of the IT (Information Technology) system as per the business-specific requirements will enable caterers to configure the data and processes as per the onboard logistics planning information in their systems. This will allow the right flights to be linked with the right galley plans.

Inflight catering is given a fresh viewpoint by the individualisation of services, which may also boost passenger satisfaction while cutting down on catering waste (Mortensen *et al.*, 2022). Therefore, Airline catering companies engage in mass customisation as they need to produce a high volume of meals with great variety every day. To satisfy airline customers and their passengers, they must make changes to the inflight products and catering services. There are significant differences in these in-flight products between airlines, cabin classes, and time periods (Chang and Jones, 2007). Mass customisation enables airline catering companies to produce a wide choice of inflight products in large volumes by following a range of airline catering instructions, catering procedures, menu profiles, meal specifications related to the airline catering supply chain, service design, and airline catering order fulfilment processes.

Airline passengers have more preferences now than ever before. There’s an increasing trend in special meal orders and reduced standard meals due to passengers becoming more health-conscious, food allergies, or religious reasons (Mortensen *et al.*, 2022). These distinct meals must be prepared in accordance with various dietary laws and religious considerations. Personalisation options are especially important for passengers with dietary restrictions or food allergies, allowing them to select appropriate in-flight meals (Priya, 2020). Nationality, culture, religion, and personal lifestyle are all factors that may increase the demand for personalised meals on board (Mortensen *et al.*, 2022). The airline catering service must deal with a diverse range of products. Most catering service providers have contracts with multiple airlines to provide catering services. As a result, there is a wide range of products derived from various factors within the airline catering industry. These influencing factors are shown in Table 2.2.

Table 2.2 Factors of inflight product and service varieties

Factors	Variabilities
Airline catering contract	Single airline / Multiple airlines
Type of flight operation	Standard scheduled flight, Chartered flight, Low-cost carrier, Executive airline
Flight duration	Domestic flight, Short-haul flight, Mid-haul flight, Long-haul flight
Cabin class	Economy, Premium economy, Business class, First class
Meal type / Time range	Breakfast, Extended Breakfast, Lunch, Afternoon, Dinner, Supper
Passenger’s preference	Pre-order meals, Special meals (E.g., Vegetarian, Vegan, Kosher, Halal, Low-fat, Low-salt)
Menu cycle	Daily rotation, Weekly rotation, Monthly rotation

Airlines are increasing pressure on catering service providers to execute their supply chain in a more cost-efficient and agile manner as part of their aggressive cost-cutting strategy (Eksi *et al.*, 2012). Catering companies are encouraged to become more flexible in their production (Gschirr, 2010), including prefabricated frozen food that can be stored and catered to flights as needed (Lin, 2018). Airlines should have a responsive supply chain due to the high degree of customisation in airline catering products and services, as well as the need for airline catering orders to be fulfilled relatively quickly.

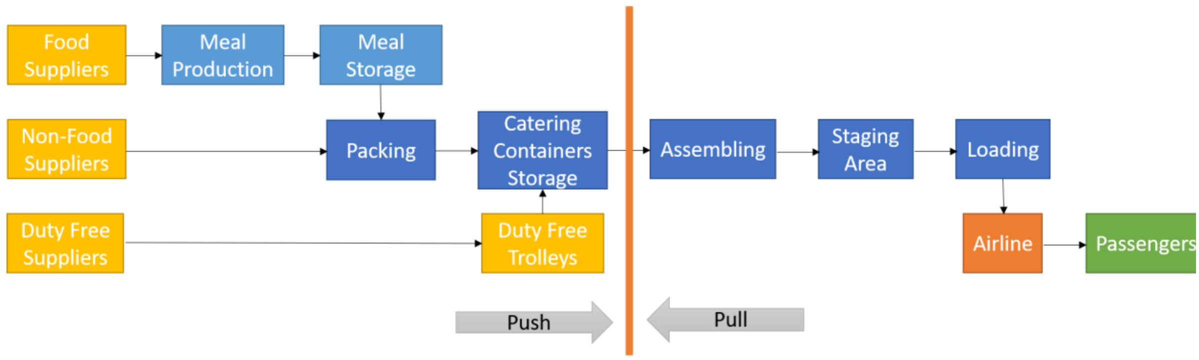


Figure 2.3 Airline catering supply chain: Assemble-to-Order (ATO)

Figure 2.3 illustrates the Assemble-To-Order (ATO) supply chain design, which is better suited for more customisable and quickly fulfilled customer orders, such as airline catering orders (Lin *et al.*, 2020). The airline catering organisation where the study was conducted, for example, has an ATO SC design in which the components of the in-flight products are assembled in the service centre after the airline order is received in accordance with the appropriate catering specifications. It reduces catering container inventory and expedites catering shipment to the aircraft (Rajaratnam and Sunmola, 2021b). Components are procured well in advance of the catering order in this airline catering environment. Some meals have already been prepared based on the most recent forecast and are ready to be assembled based on the specific catering needs.

Throughout the airline catering order fulfilment process, airlines will interact with caterers. They usually provide advance forecasts of passenger numbers and meals to caterers for catering service. The final numbers will then be confirmed to the service providers via electronic messages or phone 4 to 6 hours before the flight's departure. Catering service providers will be kept up to date on changes between the initial forecast and the final order confirmation (Thamagasorn and Pharino, 2019). After the service is completed, the catering company may be required to perform post-order processes such as invoicing by flight, responding to passenger complaints, cabin crew feedback, and other general inquiries.

In a typical airline catering operation, the airline will provide the forecasted passenger numbers on a specific flight in advance. It will then provide regular updates to the catering service provider. For example, in the case study organisation, company X's information system receives sales order details from the airline's planning and ordering system as EDI messages and creates airline orders. Company

X's information system is set up to accept these EDI messages for a flight at the time intervals listed below and update the existing sales order with the most recent changes.

- 7D (Day) – 7 Days prior to departure (Information system receives the initial airline catering order details and will create a necessary header file and item details for the sales order)
- 96QP (Query Period) – 96 Hours prior to the departure time (4 Days)
- 72QP – 72 hours prior to the departure time (3 days)
- 48QP - 48 hours prior to the departure time (2 days)
- 24QP - 24 hours prior to the departure time (1 day)
- 10QP - 10 hours prior to the departure time
- 6QP - 6 hours prior to the departure time (This is the cut-off period, this is the last order update that company X’s information system receives, and final changes will be updated in the sales records)

Figure 2.4 depicts a typical airline catering order process using the case study organisation as an example. To fulfil the customer's airline order, the catering service provider will go through a series of process steps to create the catering container with meal tray sets, ancillaries, main meals, and non-food items. The special catering truck will transport these packed containers to the airside. These trucks can be elevated up and down, and the stage can be moved to the same level as the aircraft door so that catering trolleys can easily load and unload. These sealed containers will be securely stored in the aircraft galley's designated areas. The cabin crew will then serve these meals to the passengers on board at the specified time during the journey.

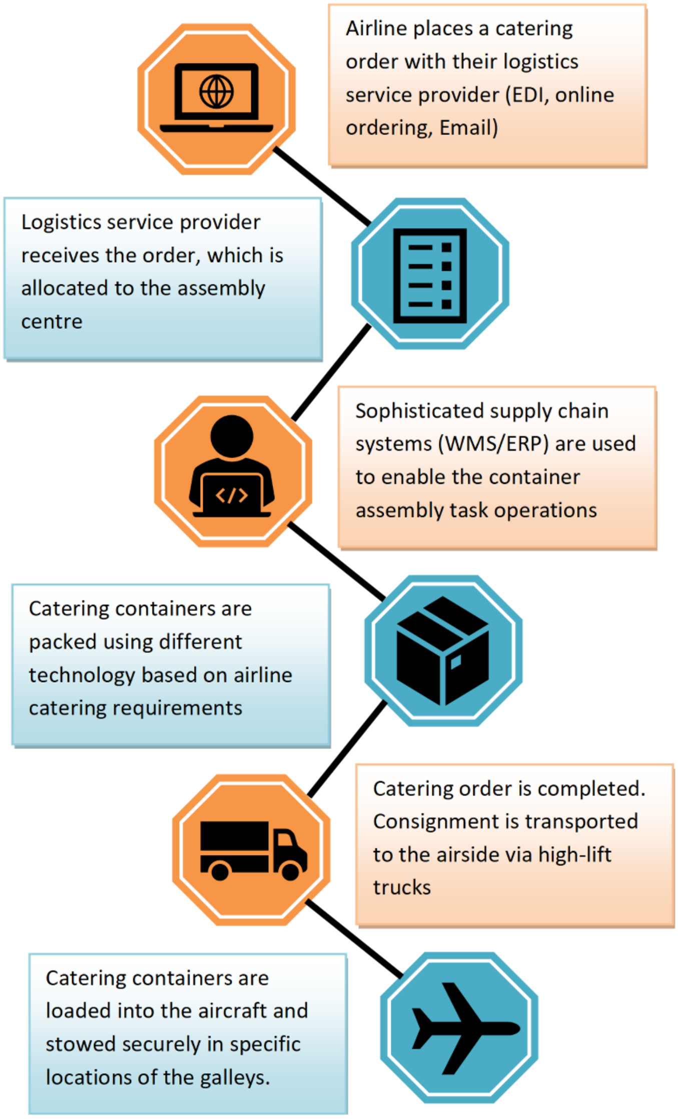


Figure 2.4 A Day in the Life of a: Airline Catering Order

All catering containers, equipment, and waste will be collected from the return flights and transported back to the service centre upon arrival. Catering waste will go through the waste management process. Containers and equipment will be cleaned and stored for future use. To achieve effective airline order fulfilment, it's essential to manage complex supply chains, apply the catering logistics principles and leverage advanced supply chain systems and technology (Rajaratnam and Sunmola, 2020b).

2.5 Fulfilling Airline Catering Supply Chain Functions

Companies are currently under competitive pressure as a result of changing market conditions, volatile demand, and technological innovations (Sharma *et al.*, 2022). These challenges must be addressed in accordance with customer demands by completing operational processes faster, cheaper, and better (Bagale *et al.*, 2021). As a result, businesses outsource internal job functions to external service providers in order to reduce operating costs and increase their ability to focus on core business activities. More businesses are focusing on their core business and outsourcing their logistics operations to professional logistics service providers in order to increase market competition (Zarbakhshnia *et al.*, 2023). This evolution is also occurring in the airline catering industry. Many companies have recently discovered new markets in the airline catering industry. This trend has influenced an increasing number of airlines to contract out catering services to catering companies, while some airlines continue to operate their own catering units. Catering contracts between airlines and service providers are typically three to five years in length (Chang and Jones, 2007). Some contracts are signed for a longer period.

Outsourcing airline catering services is becoming increasingly popular in the airline industry because it allows airlines to reduce catering costs while also serving higher-quality meals (Erdoğan, 2022). Though outsourcing logistics activities is common in many industries, culinary aspects are critical in the airline catering industry. Some airlines operate their own kitchens and supply chains. Some have direct interaction with the catering supplier, while others maintain greater control over the supply chain by outsourcing some logistics activities to a logistics service company. They assist airlines with the fulfilment of catering orders and provide logistics services.

Catering companies began to face increased competition as the airline catering industry developed significantly. Furthermore, the expansion of low-cost airlines tends to exacerbate this competitive situation (Klophaus and Yu, 2023). Airlines have become more aggressive in their cost-cutting efforts and have begun restructuring their catering systems. This significant cost pressure affects catering providers' profit margins: their meal price and overall service cost (Rajaratnam and Sunmola, 2021a). The existing catering system has undergone significant change as a result of cost pressure and increased competition. These two factors become the true motivators for airlines to outsource catering. Catering companies began to reconsider their business model for the same reason. They are still in business, but as a logistics service provider rather than a catering service provider. The majority of their meal production activities are typically outsourced to food manufacturers or meal suppliers. As outsourcing became a popular option in the airline catering industry, logistics companies were influenced to expand their services into the new airline catering supply chain market. Some logistics firms become lead logistics providers, also known as fourth-party logistics providers (4PL), and provide a full airline catering solution. They manage a significant portion of the airline supply chain. They offer services such as planning and design, sourcing and supply management, assembly operations, airport operations, final mile delivery, and returns management (Lin, 2018). This outsourcing shifts the traditional airline catering service approach from catering-led to logistics-led.

Businesses frequently choose 4PLs to manage their entire supply chain solution on their behalf. These 4PL firms assess opportunities, design and implement logistics, manage storage and deliveries, provide necessary value-added services, and measure overall supply chain performance (Kim, 2021). When airlines decide to outsource their airline catering supply chain to 4PL, they consider a number of factors. Some of the influencing factors for outsourcing to 4PL, in the opinion of the case study organisation's senior management team, are listed below:

- Can 4PL outsourcing bring significant benefits to the airline catering business strategically?
- Will outsourcing the airline catering supply chain allow airline customers to focus on their core business functions?
- Will it improve the airline's ability to be more flexible and adaptable in the changing business environment?
- Can 4PL outsourcing bring significant benefits to the airline catering business operationally?
- Will outsourcing improve the execution of current logistics processes?
- Will outsourcing enable airlines to access advanced supply chain systems and technology, give them visibility to their inventory and help airlines to increase operational efficiency?
- Can 4PL outsourcing bring significant benefits to the airline catering business financially?
- Will engaging with 4PL ensure airline customers gain more control over their commercial spending?
- Can a 4PL reduce the airline catering operating cost and the airline's working capital?

The management of the airline catering supply chain is extensive. It includes all aspects of airline catering operations, not just meal delivery, procurement, and storage. Everything from meal preparation to last-mile delivery of catering containers falls under the purview of airline catering supply chain management. Airline catering supply chain management manages every element of the airline catering supply chain, including menu planning, specification design, sourcing, supplier management, assembly operations, airport operations, final mile delivery and returns management. According to Brinkmann and Klug (2020), airline catering companies can integrate leanness upstream of the catering order and agility downstream to benefit from the balance of service orientation while also accommodating cost efficiencies. The service provider becomes the airline’s partner in streamlining the supply chain processes, and transporting meals, beverages and catering equipment, implementing a lean and cost-effective airline catering operation.

As they manage a significant portion of the airline supply chain, 4PLs are fully responsible for the overall logistics processes and catering service quality. As a result, the sustainability of 4PLs has a direct impact on the sustainability of the airline catering supply chain. 4PLs' sustainability is directly determined by the sustainable business process integration of its logistics services. One of the critical objectives of 4PL is to align people, processes and technology and manage them efficiently (Vlachos, 2021). The fulfilment of the catering function can be improved by implementing a new way of managing the complex operation. A well-experienced lead logistics service provider knows how to efficiently deal with ever demanding changes and adapt to time-sensitive airline environments.

Receiving catering orders from the airline and processing them efficiently are critical capabilities in the airline catering logistics operation. The advancement of information technology and the expansion of the internet have improved collaboration and accelerated integration among airline catering supply chain stakeholders (Ellitan, 2020). Airlines and airline catering service providers alike must embrace technology. Many organisations across industries have increased operational effectiveness as a result of technological innovation (Yusriza and Rahman, 2022). Industry-specific software applications have been developed to assist the caterers in procurement, equipment management and information exchange. In collaboration with caterers and suppliers on catering services, airlines use similar solutions to manage menu planning, meal specification design, galley planning, flight scheduling, and meal ordering (Jones, 2012a).

The successful growth of airline catering service must involve engagement between all stakeholders and users, especially airlines, cabin crew, caterers, passengers, and suppliers (Mortensen *et al.*, 2022). In the airline catering supply chain, key stakeholders, airlines, and food suppliers expect real-time and accurate information. The 4 PLs should share catering logistics information with both parties via the internet, such as current aircraft loading, the next transportation block of flights, and the status of catering containers on the way. Figure 2.5 shows an example of catering logistics information services provided by 4PL.

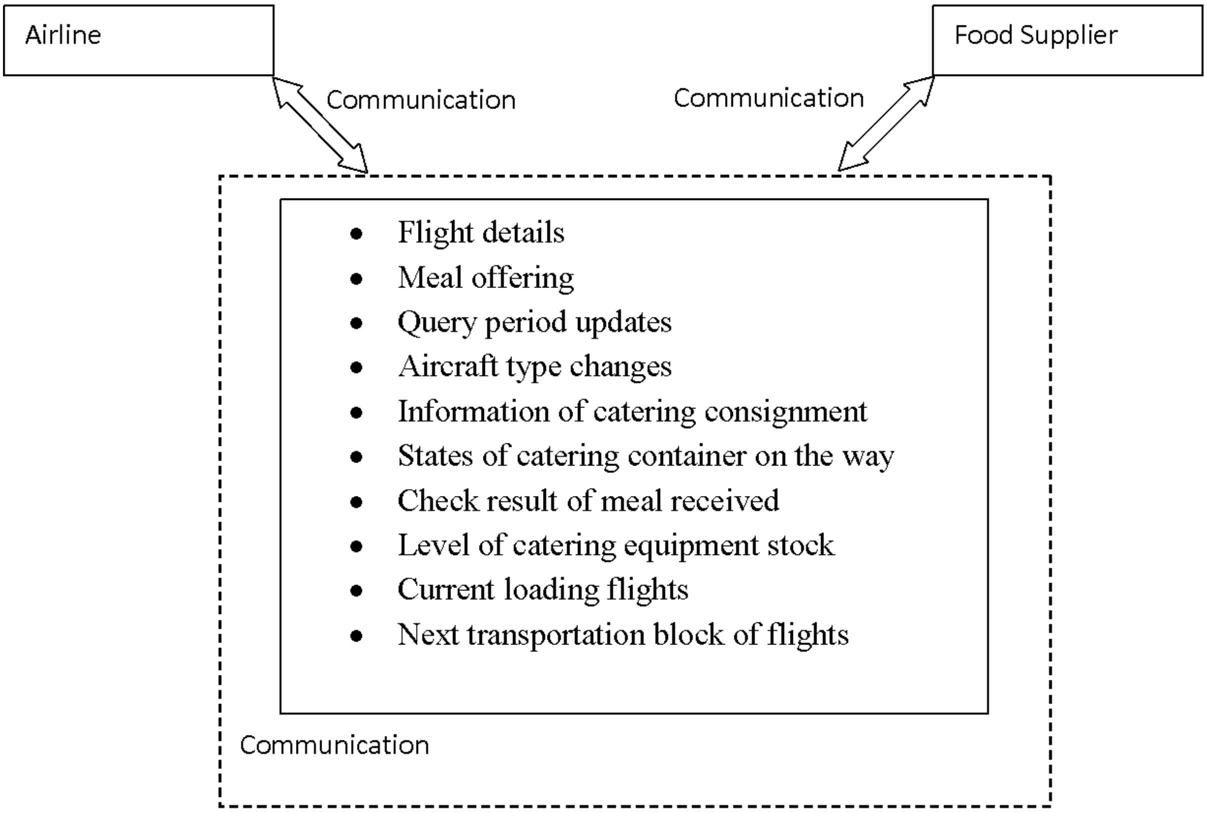


Figure 2.5 Catering logistics information services provided by 4PLs

Many advanced information and communication technologies are used in supply chain management to support the management of information systems employed by different parties. Logistics service companies use many of these techniques, such as RFID (Radio Frequency-Identification) technology, barcode technology, EDI (Electronic data interchange), web server and database technologies, to integrate business processes (Li, Liu, *et al.*, 2006). The electronic data exchange technique supports companies in exchanging business data between different applications within the organisations. It helps the logistic provider transfer the data between its partners, such as airlines and suppliers, by communicating with their systems (Werner-lewandowska *et al.*, 2023).

Airline catering operations consist of 80% logistics activities and 20% cooking processes (Sundarakani *et al.*, 2018). Logistics service providers recognise that the onboard service experience is a key factor when passengers choose the airline for their travel (Lim and Lee, 2020). Logistics service providers need to understand the catering requirements, main objectives, challenges and trends experienced by airline customers. This enables logistics companies to develop solutions that add value to the customer and continually improve their operational performance.

2.6 Airline Catering Supply Chain Practices and Performance

Airline catering industry presents a good example of the need for effectively implementing supply chain practices. As cost savings become increasingly important, airline catering service providers are also finding new ways to reduce catering costs. Airline catering companies must identify and adopt the best supply chain practices to support their catering operations (Yusriza, 2022). It is increasingly vital for the airline catering industry to effectively manage and oversee its supply chain activities to reduce costs and enhance efficient operations. The airline catering supply chain is complex and has many opportunities for practice improvement (Rajaratnam and Sunmola, 2020a). The airline catering industry recognises that effective logistics execution, a key component of the supply chain, is essential to successfully deliver airline catering service that improves customer satisfaction. A better understanding of supply chain processes, as well as the adoption of best practices is key to strengthening catering management and building logistics service capacity in airline catering supply chains.

Airline industry sector has become highly competitive due to the increase in passenger numbers. Airlines are obliged to provide better quality service to retain customer loyalty. Airlines use many ways to attract their customers with the rising competition (Chung and Tan, 2022). One of their approaches is to develop onboard services like catering services. The onboard service has a significant relationship with customer satisfaction (Siben et al., 2017). Airlines are exploring effective approaches to provide better quality service and competitive pricing by reducing catering costs and improving meal offerings. To achieve this, key performance indicators (KPIs) are essential in the service contracts between airlines and caterers. Accuracy of load, on-time delivery, value for money, hygiene and food safety, responsiveness, agility and flexible catering operations, and overall operational performance are common KPIs for airline catering service (Park *et al.*, 2020).

Supply chain agility is one of the most important priorities in the airline catering service. Supply chain is moving from the linear model to circular models whilst also incorporating agile principles. Stakeholders in the airline catering supply chain are trying to implement new strategies to achieve agility (Law, 2011). The airline catering business demands more and more innovation. Airlines want to introduce new catering products and services (Aboelsoad and Abdelmoaty, 2022). The airline market is more competitive today than it was before. The responsive time needs to go down. Ultimately, the airline catering supply chain and logistics service need to be as agile as airlines can think of new innovative ideas and business models (Ivanovic and Vujic, 2007). By improving supply chain agility and logistics process efficiency, the airline catering supply chain can consistently meet airline demand despite fluctuations in passenger numbers. They can also support airlines in controlling their catering waste through flexible catering operations (Nakornkao and Mongkalig, 2022).

Without relevant performance metrics, it's hard to monitor service performance, make decisions and difficult to control catering logistics and supply chain cost-effectively. This can lead to inefficient airline catering operations, a high inventory of expensive stock and the inability to eliminate the non-value-added costs from the airline catering logistics process. A performance measurement system is needed to ensure that various performance attributes such as reliability, responsiveness and cost are tightly connected to the logistics execution (Saleheen and Habib, 2022). Airlines can make better decisions based on performance data, and caterers can take direct action and change their logistics functions to meet the needs of the airline.

In addition, airline catering supply chains have more challenges dealing with changes and responding to emergencies during uncertain situations like the COVID-19 pandemic. The COVID-19 pandemic has posed a serious danger to worldwide supply networks, especially those of airline catering companies (Aday and Aday, 2020). The business environment and healthcare systems all around the world have been severely impacted by this exceptional challenge. Because the supply chain function is critical to many industries, including production and service functions, academic scholars and practitioners have been encouraged to investigate the solutions to prevent impending disruptions in supply chains. Unusual disruptions in the supply chain, such as the COVID-19 epidemic, are high-impact, low-frequency occurrences that cause failure in one or more supply chain nodes, potentially resulting in the inability to provide services or commodities (Kumar et al., 2018). Disruptive events present an opportunity to learn from their consequences. Learning from the COVID-19 pandemic can help enhance performance management and decision-making in the future, especially during supply chain disruptions (Remko, 2020).

Performance considerations in airline catering operations shift according to business priorities, as evidenced by the COVID-19 pandemic. Existing performance measures in the airline catering supply chain are too rigid and must evolve to manage uncertain periods. Airline catering organisations face challenges in reengineering their performance measurement system with fair and meaningful objectives in this ever-changing, uncertain airline business environment. They require a methodology for establishing agile performance measurement, which consists of timely recognised appropriate performance metrics that adapt as performance considerations change in order to track and influence better performance.

2.7 Sustainability Need for Airline Catering Supply Chain

International tourism relies on air travel. The unprecedented growth in the tourism industry has created the waste problem in the airline industry. The growing passenger numbers, increased number of flight operations, and new types of commercial aircraft contribute to solid waste formation. Therefore, waste management becomes a key issue for airport operations and is a challenge the airline catering industry consistently faces (You *et al.,* 2020). According to research done by IATA, it was quantified that 5.7 million tonnes of cabin waste were generated by airlines in 2017. Looking at the current growth rate in passenger numbers, this volume is projected to double in the next ten years (IATA, 2019). For example, waste from Heathrow airport operations is estimated at 25,000 to 40,000 tons per year, 70% of which is through catering (Thamagasorn and Pharino, 2019). Cabin waste consists of two main elements in flight operations: cleaning waste and catering waste. Cleaning waste comes from the items provided to the passengers on board. Catering waste is made up of leftover materials from inflight meals. With most of the waste generated from catering services, sustainability concerns are becoming significant challenges in the airline catering supply chain (King, 2001). Catering waste is caused by the inflight meals, beverages and snacks that are served to the onboard passengers. They are made up of leftover food, packaging materials and excess drinks. It can also include a large number of unused beverages, snacks and ice. There are around 630 flight kitchens globally, and each kitchen supplies more than one million meals per year (Chang and Jones, 2007).

Meals are often regarded as the least expensive resource in aircraft catering services. Overproduction and catering to avoid meal shortages are the primary causes of food waste. According to a pilot study conducted at London Heathrow Airport in 2012 and 2013, the cabin waste generated by a common passenger is an average of 1.43 kg across both short-haul and long-haul flights from different airlines. The study further indicated that 23% of this waste is caused by untouched meals and beverages (IATA, 2014). Meal production is dependent on airline catering orders, which change frequently due to a drop in passenger numbers or other uncontrollable factors such as flight cancellations and delays. However, it poses a significant sustainability problem due to the loss of valuable calories and soil fertility, increased energy and water consumption in food production, and increased waste management costs for governments (Nakornkao and Mongkalig, 2022). To address the sustainability issue, Current practices in the airline catering supply chain need to be reviewed and required changes must be implemented.

Airlines recognise the importance of reducing their environmental footprint. To comply with government waste regulations, they are looking into all possible options to minimise waste. Reducing waste is one of the critical sustainability strategies for airlines (Jones, 2012b). As per the DEFRA (Department for Environmental Food and Rural Affairs) guidelines, Airlines need to apply the waste hierarchy to their catering waste (DEFRA, 2011), as illustrated in Figure 2.6. They rely on airline catering service providers' support in preventing, reusing and recycling the catering waste from catering operations to reduce its impact.

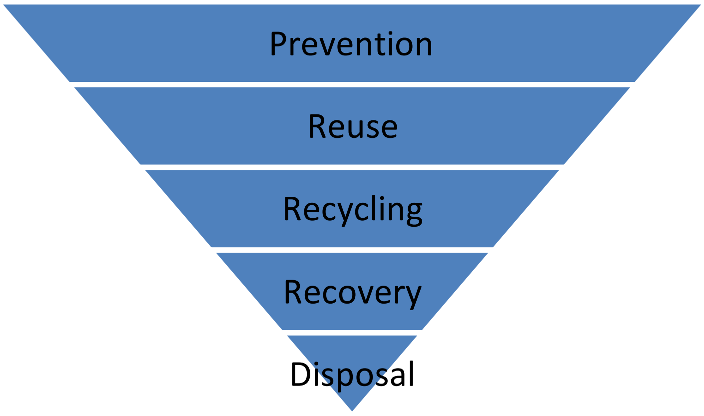


Figure 2.6 Catering Waste Hierarchy

Airlines have started effective recycling of food and using environmentally friendly packaging with the support of systems and technologies. While this initiative avoids landfilling, it also provides a new source of revenue stream for airlines (Salesa *et al.*, 2023). Single-use plastics contribute to catering waste and passengers are concerned about disposable plastics. Catering service providers introduce sustainable alternative packaging and recycling solutions to reduce waste. They can eliminate plastic waste by sourcing biodegradable cutleries and cups. Governments encourage the reduction of food waste. Airlines needed to comply with the industry's commitment to reducing CO2 emissions. To support this, airlines are keen to implement carbon reduction projects and initiatives. This includes operating more fuel-efficient aircraft, managing catering waste, and reducing catering load (Antoni *et al.*, 2020). Prevention of catering waste is the most preferred method, and disposal is the least preferred method in the catering waste management hierarchy (Nakornkao and Mongkalig, 2022). Catering service providers support airlines with waste reduction initiatives. Some initiatives are buy-on-board service, pre-order meals at check-in, and pre-paid meals. They also perform recycling activities as per the regulations. Implementing good supply chain practices to control catering waste prevention and reduction, will reduce the amount of waste that reaches landfills through disposal. This includes supplier management, inventory management, good menu planning, appropriate workflow design and required training (Thamagasorn and Pharino, 2019). Reverse logistics must implement proper catering waste management to reduce the environmental impact. They collaborate with recycling companies to transform biofuel from organic catering waste instead of traditional waste disposal methods, as food waste that ends up in landfills or oceans creates additional environmental burdens. Its organic contents are easily biodegradable and generate greenhouse gases such as carbon dioxide (CO_2) and methane (CH_4) in the atmosphere (Mahmood *et al.*, 2016). Additionally, there are some challenges in handling catering waste from international flights due to the regulations that enforce some restrictions based on health concerns. These wastes are classified as high risk because it may be possible to transfer disease between the countries if these international catering wastes are not handled and disposed of appropriately. Catering companies adopt waste management regulations and continue to support more recycling while ensuring human and animal health concerns.

Aside from environmental concerns, airlines are becoming more concerned with corporate social responsibilities (CSR) (Kuo *et al.*, 2021). Catering service providers assist airlines in making charitable donations to communities through partnerships with other aid organisations or airline-owned charity foundations. A catering company can collaborate with airlines to implement CSR initiatives such as donating excess food to charities. They recover many untouched meals from return flights, such as packed snacks, biscuits, unopened drinks, pre-packaged sandwiches, and bakery products.

Airlines are concerned about their airline catering supply chain's ability to respond to waste management challenges (Mortensen *et al.*, 2022). A few of the main challenges that airlines face related to catering waste are a lack of awareness of food waste volume and cost, no visibility of waste cost in service contracts, and a complex relationship with the key stakeholders in the catering supply chain. Catering companies do not have a comprehensive mechanism to collect such data. They are encouraged to collect data with reference to the type, amount and cost of waste and share these details with the airlines and propose and support waste reduction initiatives. They also monitor the waste performance improvement results. Catering service providers implement standard operating procedures that support waste segregation by reusables and recyclables in their facilities. They are committed to minimising catering waste by analysing the passenger consumption data, reusing the catering equipment effectively, and recovering untouched and non-perishable food items. They enable airlines to donate non-perishable food items to charities or sell food to raise funds for charities.

Though Airlines generally do not manage the catering waste collection, they still hold the responsibility for minimising the catering waste. Catering service providers usually perform this job. Airline catering service providers are also responsible for the return logistics. They need to manage the reverse flow of the catering equipment and the catering waste from the return service flights. They collect, store, and dispose of the catering waste as part of their reverse logistics process and support airlines in meeting their suitability objectives. Since caterers normally collect the catering waste, it's challenging for airlines to carry out the catering waste analysis due to minimal data and no integrated corporate information reporting. Catering service providers must adopt a standard catering waste analysis methodology. They can actively conduct consumption analysis to assist airlines with waste reduction efforts by suggesting meal provisioning changes, reducing beverage loading, and designing alternative meals (Nakornkao and Mongkalig, 2022). An airline catering organisation can serve multiple airlines at the same airports; hence it's vital to have a system to segregate and monitor the waste for each airline. The use of an effective information system will enable catering organisations to have clear visibility of waste reports by flight routes. So, they can share the analysis results with airline customers to help them make better decisions.

2.8 Chapter Summary

This chapter provides a contextual analysis of the airline catering supply chain and demonstrates that supply chain management as a strategic function can add economic value to both caterers and airlines. It analyses the competitive business environment, presents the structure of the airline catering supply chain, details its operations and outsourcing practice as part of the service fulfilment function. It provides an example from the case study that recognises the Assemble-To-Order (ATO) supply chain design is suitable for airline catering business that engages in mass customisation and requires a responsive supply chain. The chapter briefly discusses the key points relate to airline catering supply chain practices and performance. Further, it elaborates on the sustainability requirements in the airline catering supply chain.

3 Literature Review

The primary focus of this literature is to review the previous studies on performance and practices in the supply chain field. This section also presents the supply chain operations reference (SCOR) model, including concepts, structure, and application of the SCOR model in different industries. It then discusses the effects of the COVID-19 pandemic on the supply chain and airline business. Finally, this study emphasises the research gap for adopting the SCOR model in the airline catering industry.

3.1 Supply Chain Operations Reference Model (SCOR)

The supply chain operations reference model (SCOR) is a unique framework that provides the methodology and diagnostic tools for organisations to understand their supply chain processes (APICS, 2017). This model connects people, processes, best practices and performance metrics within a structured framework (Kusrini *et al.*, 2019). It is currently the most recognisable and reliable supply chain management framework which helps supply chain professionals identify the critical features for customer satisfaction and improve supply chain management effectiveness. This reference model was developed and endorsed by the Supply Chain Council (SCC) (Delipinar and Kocaoglu, 2016) and enables practitioners to define strategy, manage business processes, and measure performance. It has evolved based on extensive feedback from industry leaders who manage supply chains and apply the reference model regularly to improve business performance. SCC merged with the American Production and Inventory Control Society (APICS) and became known as APICS SCC. The APICS SCC has released its most recent version of the framework, SCOR 12.0 (Girjatovics *et al.*, 2018), which comprises six primary management processes plan, source, make, deliver, return, and enable (Lemghari *et al.*, 2018) and four major components: performance, processes, practices, and people. It also includes GreenSCOR as the extension of the framework, which incorporates environmental considerations (Ntabe *et al.*, 2015). A large number of organisations and companies have adopted the SCOR model (Kottala and Herbert, 2019). Various industries have benefited from applying the SCOR model, e.g., the construction industry, tourism industry, petroleum industry, automotive industry, technology industry, and service industry (Ntabe *et al.*, 2015). A few examples of case study applications in different sectors where the SCOR model has been used in the past are summarised in Table 3.1.

Table 3.1 Applications of SCOR model in different industries

Application Areas	SCOR Model Application	Reference
Airline Catering Industry	The SCOR model is applied in the context of airline catering service to develop performance metrics for their supply chain and explore the choices of metrics during the COVID-19 pandemic emergencies.	(Rajaratnam and Sunmola, 2021b)
Automotive Industry	The SCOR model is used to design the performance improvement strategy in automotive companies by understanding the priorities of key performing indicators defined in each supply chain process and performance attributes of the SCOR model.	(Dianawati and Zamzamy, 2021)
Construction Industry	The SCOR model is used to analyse the business processes of a construction company and to calculate the supply chain performance measurement.	(Rizkya *et al.*, 2019)
Defence Industry	The SCOR model is used to model the different supply chains of the South African National Defence Force and applied with other supply chain management principles to improve their military logistics effectiveness and inventory management.	(Bean *et al.*, 2005)
Footwear Industry	The SCOR model is applied in the context of the footwear industry with its two dimensions: processes and performance standards, to model a performance measurement for its supply chain.	(Sellitto *et al.*, 2015)
Healthcare Industry	This SCOR model is used to implement an analytical hierarchical process to measure the performance of four important departments of a hospital by considering five performance criteria: reliability, responsiveness, agility, costs, and assets.	(Nateghinia *et al.*, 2013)
Humanitarian aid Industry	The SCOR framework is applied to the humanitarian aid supply chain context to identify the most critical performance metrics for humanitarian logistics operations by examining their supply chain processes.	(Lu *et al.*, 2016)
Information Technology Industry	The SCOR framework is used to develop a comprehensive supply chain management problem-solving methodology.	(Dong *et al.*, 2006)
Leather Industry	The SCOR model is used to measure the supply chain performance of a leather bag production company and define the company's overall supply chain performance.	(Kusrini *et al.*, 2019)

Petroleum Industry	The SCOR model is used to map the oil industry's upstream and downstream supply chain processes.	(Maizi *et al.*, 2020)
Pharmaceutical Industry	The key performance indicators of the SCOR model are used along with other financial metrics to measure the supply chain performance of different segments of pharmaceutical firms in India.	(Tripathi *et al.*, 2019)
Retail Industry	The SCOR model is used to analyse the supply chain risk factors in the various phases of the retail supply chain, such as planning, purchasing, sales, delivery, and return.	(Huo, 2011)
Telecommunication Industry	The SCOR model is applied for supply chain modelling and improvement in the telecom industry, and the benefits of the SCOR model implementation are analysed.	(Xia, 2006)
Transport Industry	The SCOR model is applied to examine the service operations performance in the Dubai Metro transportation service.	(Kamarudeen *et al.*, 2020)

The SCOR model is organised around six primary management processes (plan, source, make, deliver, return and enable) at the top level. The top-level major processes define the scope and content of the supply chain. Level 2 is the configuration level, which is linked to process classification. This is completed at level 2 by identifying categories for each process type at level 1. The process category is organised at level 2 in accordance with the supply chain strategy. Organisations put their operations strategy into practise by deciding how to set up their supply chain. The lowest level in the scope of the SCOR model is Level 3, which is the level for process elements. At level 3, processes are decomposed. Organisations adjust their operations approach precisely at this level to make their supply chain more effective and successful by defining information inputs and outputs, system capabilities and best practices. The next level is the implementation level which decomposes the process elements further into specific tasks and activities to implement and manage the supply chain as per the changing business environment (Suseno *et al.*, 2018).

The model helps organisations evaluate their supply chain's design to make improvements and identify any redundant and inefficient practices along their supply chain to eliminate them. Figure 3.1 shows the schematic representation of the SCOR model adapted for this research related to the airline catering supply chain. Though it covers all customer interactions, physical materials interactions and market interactions, it does not intend to define every business process or activity. Mainly, it does not cover business processes like sales and marketing, research and development, and product development. As a business framework, it explains how these major processes interact, the link between supplier's supplier to customer's customer is configured, and the understanding of the demand for order fulfilment (Kamarudin and Zarirah Nizam, 2022). The SCOR model is a flexible and customisable framework that can be adapted according to business requirements and applied to different industries and conditions (Tunyaplin and Chanpuypetch, 2021). However, practitioners should be aware of the particular specifications of the industry's distinctive features while using the SCOR model for problem analysis through benchmarking (Ruamsuke and Ongkunaruk, 2021). The SCOR model helps define the organisation's processes for all stages of supply chain activities. It also classifies supply chain performance metrics to measure whether processes are being effectively managed and business goals are being met (Lima-Junior and Carpinetti, 2020).

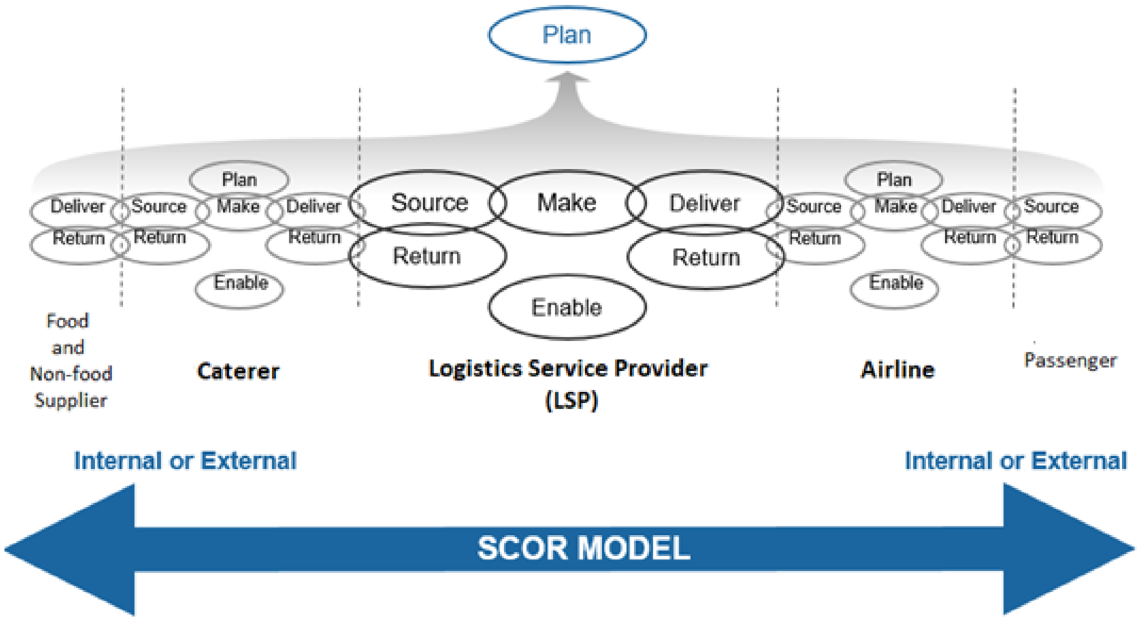


Figure 3.1 Organisation of SCOR management processes
Adapted from SCOR Model Version 12.0 (APICS, 2017)

SCOR framework was designed to evaluate the efficiency and effectiveness of the supply chain. It provides a framework for processes, performance metrics and practices linked into a unified structure (Puffal and Kuhn, 2018). It uses common, standard definitions that can be applied to any supply chain across any industry. It consists of well-defined metrics for performance measurement and integrates supply chain practices for supply chain improvement (Prasetyaningsih *et al.*, 2020). The framework helps businesses regularly assess their supply chain for reliability and consistency by judging their business processes and supply chain practices and ensuring they perfectly align with their strategic goals. Many organisations develop their performance measures and implement supply chain practices based on the SCOR model (Ayyildiz and Taskin Gumus, 2021). The model categories all performance metrics under five performance attributes which describe performance from two viewpoints. The first viewpoint comes from the client which is expressed as customer-facing attributes which include reliability, responsiveness and agility, whereas the second is referred as internal facing attributes that come from within the company, for example, costs and asset management (Hidayat *et al.*, 2020). The literature reveals that there has been increasing attention to the SCOR framework recently, and different industries have widely adopted the model over the years to improve supply chain performance. The SCOR model recognises several supply chain best practices within organisations (Georgise *et al.*, 2013). The SCOR v12 framework distinguishes 21 practice categories that help practitioners identify their supply chain's focus area (APICS, 2017). The SCOR framework links performance metrics and supply chain practices into a streamlined structure (Akkawuttiwanich and Yenradee, 2018).

3.2 Supply Chain Management, Processes, Performance and Practices

3.2.1 Supply Chain Management and Logistics Operations

Typically, a product reaches the customer through the process of transforming raw materials into a finished product and distribution processes. This is achieved through a collaborative effort of multiple organisations. These organisations are linked together by the flows of products, information, and finance and form the supply chain (Liu and Wang, 2014) that eventually fulfils customers' requests by presenting a final product to them. Suppliers, manufacturers, distributors, retailers and customers are the common organisations involved in the supply chain (Gohil and Thakker, 2021). Supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage through to the end-user, such as purchasing raw materials, making products, giving them to the customer, etc (Dubey, Singh, *et al.*, 2020). Supply chain management is the integration of supply chain activities through improved supply chain relationships between all parties.

Supply chain management manages these flows efficiently to minimise cost, maximise profit and improve customer service. Today, it is one of the important factors that determine the ways to obtain competitive benefits in modern organisations. Qi (2008) suggested that the successful implementation of effective supply chain management will help the organisation increase profitability and productivity while reducing cost and risk, hence improving overall organisational competitiveness. Information Technology plays a vital role in achieving all these advantages, which can be achieved by creating harmony between all supply chain parts through efficient information exchange (Baah, Opoku Agyeman, *et al.*, 2022). Since Supply Chain Management is a broader term involving various disciplines, the definition of Supply Chain Management can be ambiguous, and it is often confused with logistics management (Li, 2014).

The Council of Supply Chain Management Professionals (CSCMP), involved with industry experts, created the official definition of the terms Supply Chain Management and Logistics Management (CSCMP, 2021). "Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, Supply Chain Management integrates supply and demand management within and across companies."

According to CSCMP, "Logistics management is that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements." While Supply Chain Management is responsible for coordinating major business functions and processes within and across organisations (Lambert and Enz, 2017), logistics management includes inbound and outbound movement of goods, materials management, warehouse management, and order fulfilment. To a certain extent, the logistics function also covers procurement activities, production planning, and packing and assembly services (Li, 2014). We can consider logistics operations as the functional component of Supply Chain Management. Supply Chain Management comprises logistics execution as well as the coordination and collaboration of business partners and functions (Tiwari, 2021). Effective logistics involves the integration of information and automates process links. The goal of the logistics function is to ensure that the right items in the right quantity are available at the right time at the right place in the right condition (Skurpel, 2020).

Li (2014) has stated an issue in the supply chain behaviour that organisations in a supply chain do not make improvements commercially at their partner's expense but rather create the supply chain more economical as a whole. But, this should be considered as a competitive advantage rather than an issue. The modern supply chain is more transparent, and supply chain partners support each other. The ultimate goal of SCM is to minimise cost, maximise profit and improve customer service (Jifroudi *et* *al.*, 2020). This can only be achieved through collaborative success in managing all resources efficiently (Daugherty, 2011).

Earlier research literature regarding information technology in the supply chain mainly represented internet usage in many cases. In a number of recent literature works, the use of information technology and its objectives in the supply chain have been examined, including information availability and visibility as well as decision-making based on supply chain data (Messina *et al.*, 2020). Effective decision-making always requires accurate and on-time information, which can only be achieved by information technology support (Wei *et al.*, 2020). Traditionally, research in the supply chain has aimed to acknowledge the substantial effect of information technology on the development of supply chain management, such as various IT applications usages. Because of the influence of information technology, supply chain management has become effective; almost all critical business processes have been integrated, and separated business functions have been streamlined.

Different software systems are available to support supply chain management functions. Previous studies show that Enterprise Resource Planning (ERP) systems and Supply Chain Management (SCM) systems are the most common supply chain software applications in use (Tavassoli *et al.*, 2009). Three essential abilities of these information systems are collecting and communicating data, storing and recovering data, and processing data and reporting information. The primary aim of adopting an ERP system is to integrate all business activities within an organisation (Mahar *et al.*, 2020). In contrast, the SCM system extends its functionalities across multiple organisations along the entire supply chain (Chiang *et al.*, 2021). Usage of Supply Chain Management (SCM) systems has brought significant benefits to enterprises. These benefits include improved inventory control, shipping accuracy, increased productivity, improved forecasting and demand planning, and reduced lead time (Misra *et al.*, 2010).

It is critical to comprehend the connection between supply chain practices and supply chain performance. Numerous recent supply chain studies have focused on supply chain performance and procedures. Resource, output, and flexibility measures are a few essential types of performance measures in a typical supply chain performance measurement system (Lee *et al.*, 2022). Despite supply chain organisations' development plans and market rivalry differences, the goals of supply chain system design are the same. The common goals are to lower the organisation's costs, enhance revenues, and improve customer satisfaction (Kamalahmadi *et al.*, 2022).

There is a link between supply chain practices and financial and non-financial performance; supply chain practices can lead to achieving a company's strategic goals (Okongwu *et al.*, 2015). For the purpose of realising improvements in business performance, it is necessary to improve supply chain practices such as materials planning, inventory management, capacity planning, upstream logistics, and downstream logistics (Fantazy *et al.*, 2010). Although there is a measure of an understanding of the importance of supply chain management practices to supply chain performance, some supply chain organisations do not effectively implement the practices due to the challenges they face, such as lack of financial resources, lack of appropriate continuous improvement commitment, and low process technology integration (Demberere and Kasongo, 2021). Furthermore, some organisations have difficulties in prioritising the most important practices to implement effectively in relation to perceived business performance.

The existing literature acknowledges several challenges in supply chain management. Some of these challenges include product variation, shorter product life cycles, more demanding customers, volatile markets, increasing logistics complexity, and globalisation (Chhetri *et al.*, 2022). These are evident in the airline catering supply chain too. It is compulsory that all industries, including airline catering, modernise their supply chain to make them agile, flexible, and responsive to handle the pressure of global competition (Misra *et al.*, 2010).

Supply chain management is seen as one of the industries most likely to benefit from artificial intelligence applications. The enormous number of studies involving AI show that there is a lot of interest from both supply chain practitioners and academic researchers (Riahi *et al.*, 2021). Artificial neural network, Fuzzy logic, Agent-based systems, data mining, and case-based reasoning are some of the popular techniques among the several AI approaches used in supply chain management (Pournader *et al.*, 2021). Supply chain generates vast volumes of data and necessitates quick decision-making. Thus, it’s strongly advised to adopt AI technologies for big data analysis and decision support systems. AI enables efficient optimisation and network orchestration improvement that is impossible for humans to do. The broad application of AI depends heavily on advancements in computer chip technology. Using computer chips for tracking is essential since logistics deals with transportation. Due to the fact that tracking produces a lot of data that may be analysed and evaluated for a variety of reasons (Dubey, Gunasekaran, *et al.*, 2020). AI may assist supply chain industry in redefining current supply chain practices by transforming operations from reactive to proactive, moving from manual processes to automated, offering standard service to customised service, and planning demand from forecasting to prediction using interactive decision-making systems, robotics process automation and data analytics (Toorajipour *et al.*, 2021).

Supply chain organisations are exploring blockchain technology these days because it gives access control, immutability, transparency, and trust among supply chain players. Blockchain technology could contribute to achieving supply chain management objectives including cost, speed, risk mitigation, flexibility, and sustainability (Lim *et al.*, 2021). It is a distributed ledger that stores a history of assets and transactions between all supply chain participants, who are connected to a decentralised peer-to-peer network, distributing transaction data to all participants equally, resulting in a concurrently recorded version of the transaction (Joshi *et al.*, 2022). The earlier blockchain literature in the supply chain management field mostly pertains to supply chain traceability and product provenance, transaction automation, and data security. Other studies have looked at the function of blockchain technology in supply chain operations, such as transportation bookings, invoicing procedures, and inventory management (Musigmann *et al.*, 2020). Researchers suggest that using blockchain technology increases data integrity, which benefits data transmission between supply chain parties. However, communication among stakeholders is simple but unreliable due to the fact that many existing implementations are unable to offer a dependable system for those involved in a supply chain.

Supply Chain Management is an evolving discipline; more innovations are happening in this field. There are lots of research being carried out by academics and industry practitioners. According to the finding from the earlier literature, the trend in direct observation research methods in supply chain and logistics research has increased like case studies. However, the researchers may need to deal with some ethical issues in this data collection method. Moreover, there will be a possibility of behavioural changes in the sample with adverse implications for the research. This delicate situation may be manageable depending on the relationship between the researcher, organisation, and participants. Survey methods are prevalent in SCM research. Survey-based research has been predominantly utilised in investigative research. This trend has been moving towards model building and testing (Sachan and Datta, 2005). However, this qualitative research method is discipline-oriented and may not serve best for information system-based solutions. It'll be more efficient in the collaborative use of suitable information system research methods such as design science research methodology, which provides principles and guidelines for system designs.

3.2.2 Business Process Management in Supply Chain

Logistics and Supply Chain Management enables today's business organisations to improve their overall performance and enhance their ability to stay completive in the marketplace. Logistics and supply chain integration is defined as the best industry practice for gaining competitive advantages (Novais *et al.*, 2020). Supply chain integration has a favourable influence on company performance as an operational capacity in the field of supply chain management. One of the primary organisational activities within supply chain integration is to emphasise the exchange of strategic information on value creation in order to acquire a competitive edge (Cheng *et al.*, 2022). Existing literature reveals some of the benefits of this integrated supply chain and logistics function such as lower total cost, higher quality and increased level of customer service (Mellat-Parast and Spillan, 2014). Though information technology plays a vital role in developing an efficient supply chain system, previous research in this field suggests that it is important to pay attention to business process reconfigurations and focus on information systems and related communication technologies (Mellat-Parast and Spillan, 2014). It is important to acknowledge the customised information systems that best suit specific industry needs.

Logistics and Supply Chain Management form the backbone of any business. Supply chain is becoming increasingly complex operations, and more organisations rely on enterprise information systems to manage their business processes (Sena Nugraha *et al.*, 2020). The existing ineffective practices, lack of performance measures and multiple non-integrated enterprise systems are possibly far from the best business process management standards. This will cause supply chain organisations to miss business improvement opportunities. An effective information system is necessary to successfully deliver logistics service that improves customer satisfaction. Implementing a logistics management information system is a critical step for businesses to increase their logistical efficiency (Li and Wu, 2021). Better access to and use of business information is key to strengthening supply chain management and building logistics service capacity in the supply chain (Tarigan *et al.*, 2021). As such, supply chain organisations require the expertise to understand enterprise systems and perform functional analysis work to facilitate industry-specific solution development and business process integration opportunities.

Businesses have challenges in implementing effective logistics execution. Embedding the operations strategies in business process integration is vital to support the supply chain organisations in meeting their service level objectives. The complex nature of the supply chain has led to an increased need for integration in many functional areas of its logistics operations. There are different types of SCM technologies available for the efficient and successful supply chain management. Enterprise applications such as Enterprise Resource Planning (ERP) System, Transportation Management System (TMS), Warehouse Management System (WMS), and Manufacturing Execution System (MES) are being used by large and medium-sized companies in the supply chain to facilitate this functional integration and to assist their departments in running the day-to-day business (Pattanayak and Punyatoya, 2020). The cost of these systems' deployment and maintenance is high. Data management and configurations of these enterprise-wide information systems are complex, and it prevents greater flexibility in dealing with business challenges, pursuing new business opportunities, and increasing profitability (Aier *et al.*, 2021). These systems are an immense investment for an organisation; hence they always demand suitable functionalities to meet their requirements (Robert Jacobs and ‘Ted’ Weston, 2007). Since many of these systems are standard application packages, the functional processes of these systems are not necessarily the best fit for the specific business needs of a particular industry sector like airline catering. Achieving a better-integrated business process solution within the airline catering supply chain involves identifying cross-functional processes in its logistics operations and exploring how the core features of supply chain systems such as ERP and WMS systems might be customised more efficiently and simply to support the business needs.

ERP solutions are now necessary for organisations in the Industry 4.0 era to operate in a dynamic and fiercely competitive business environment. Currently, it serves as the basis of efficient information management and the backbone of corporations. It is essential to an organization's development and sustainability (Qureshi, 2022). Organisations are progressively implementing and updating their information systems, especially ERP systems, to address operational difficulties and enhance supply chain response. An ERP system is a comprehensive collection of application software that supports numerous organisational tasks and procedures. ERP systems are supposed to offer value to supply chains by facilitating integration, improving communication among internal and external stakeholders, and streamlining decision-making processes (Falagara Sigala *et al.*, 2020). By incorporating blockchain technology with existing ERP software, both systems will be able to interact for the finest supply chains. This implies that businesses may keep their ERP systems while still joining a single blockchain network governed by rules (Hader *et al.*, 2021).

Particularly experienced ERP vendors have worked on several projects across a wide range of sectors. In many instances, proprietary ERP applications for specific industries have already been created that already serve as a standard solution to address a wide range of business requirements. Proprietary ERP software also needs some initial customisation. Yet this customisation is supported, when needed, by the ERP vendor or a licenced service provider. Some airline catering business-specific processes, such as galley and stowage planning and in-flight menu planning, are not better served by proprietary ERP software systems. These systems need to be significantly modified. Extended ERP capabilities could enhance return on investment and add value to the business when combined with effective ERP utilisation in the airline catering business (Ruivo *et al.*, 2020). Small and medium-sized enterprises can't afford proprietary ERP software because of time and financial constraints. As a result, those businesses have a greater need for ERP solutions that are developed in-house or using open source. Lee *et al.* (2011) discovered that small and medium businesses use open-source applications for different functional modules created and offered by commercial developers as per the specific business requirements. In previous research, Olsen and Sætre (2007) argue that the in-house development of ERP systems is the most effective way to satisfy business demand for many small and medium-sized businesses. As a result, the company can implement precisely the system that it requires and adapt the system to meet the needs of the business. Yet, the decision must be based on the organisational needs, regardless of whether a company chooses proprietary ERP applications or other alternative ERP solutions. The business requirements of the organisation must be taken into consideration when choosing the type of ERP system to use. Organisations must think about system capabilities, cost and time while making such a choice.

More important is the fact that an ERP system, whether a standard proprietary system or an in-house developed solution, needs to be customised to serve the specific requirements of the business. There is always a gap between the system processes and the business processes in the organisation. To address this gap, organisations may need to customise their information system functionalities or reengineer the current business processes or consider the combination of both options (Parthasarathy and Sharma, 2016). Reengineering business processes may not be an easy option for some organisations due to the complex nature and unique features of the business environment. A customised logistics execution system can support the increased complexity of logistics operations in the supply chain by integrating all the logistics business processes. It will allow organisations to manage the flow of information and processes involved in their supply chain throughout all the stages, from procurement of materials to final delivery of the products to customers.

However, customising an enterprise system to enable business process integration and meet specific industry requirements is challenging. This is evident, particularly in the airline catering industry, due to its unique business processes and complexity. Services and business process improvements are the primary components of the entire procedure improvement in the airline sector. Business process improvement has realised the significance of getting enhanced quality at a significantly lower cost and time cycle (Zakir *et al.*, 2023). The introduction of IT created new opportunities for enterprises. Many of them are interested in solutions that focus on business processes and manage them better to increase their operational efficiencies. Business process management is a novel initiative in the enterprise architecture discipline that gets more attention from academic and professional communities in business management and IT fields. Today, many businesses, including the supply chain, use this structured method to improve their business processes, leading to greater efficiency and profitability. Business process modelling is the core enabler of business process management, which provides the graphical representation of business processes and workflows in an organisation to recognise potential improvements. It is one of the most critical steps in customising or developing an enterprise system. Business process modelling lays the foundation for implementation success and offers the opportunity to discover current weak points and design future improvements. Creating a suitable business process design framework is required to support the business process integration of logistics functions in the airline catering supply chain.

3.2.3 Supply Chain Performance

Supply chain is an essential part of businesses that seek growth and profitability. Evaluating the effectiveness of supply chain management strategies to improve its performance has become increasingly important (Lima-Junior and Carpinetti, 2020). The maximisation of a chain's effectiveness through the provision of greater service to the final consumer is one of its main objectives in supply chain management. In light of this, supply chain performance serves as the foundation of supply chain strategies, but measuring it is challenging due to the observation of both quantitative and qualitative factors, such as flexibility and delivery capability, in addition to economic factors like sales volumes and costs. It is important to continually improve on approaches for measuring the performance of an organisation’s supply chain. The supply chain performance measurement system consists of metrics that help organisations quantify the effectiveness of their supply chain. The metrics provide meaningful information about historical events to the management to assist them in making informed decisions regarding future performance. Identification of the performance metrics that establish the overall performance is crucial for measuring supply chain performance. These performance metrics describe the ability of supply chain processes and regularly demonstrate the efficiency with which supply chain processes are carried out (Kottala and Herbert, 2019).

The performance of the supply chain is critical to the proper functioning of economies. Failures can lead to bottlenecks that have a negative impact on productivity and economic growth (Salvatore, 2020). Nevertheless, Supply chains have many dimensions, and their coordinated operation is critical to the timely and smooth delivery of products to customers and contribution to businesses (Elekdag *et al.*, 2015). While understanding the performance of the supply chain is not new, supply chain performance attributes such as reliability, responsiveness and agility have drawn renewed attention following the recent COVID-19 crisis. Governments around the world have moved with urgency to ensure sufficient supplies of medical equipment and vaccines, avoid unnecessary transportation disruption, and guarantee consistent food supplies. The pandemic condition hastens the expansion of e-commerce and also has a strong impact on customer behaviours. Deliveries, storage, and quality control during distribution are just a few of the additional problems that manufacturers and retailers must contend with.

The literature on supply chain performance measures has evolved. Many authors have proposed many frameworks that shift the focus from performance measures to performance measurement systems. Many studies have been conducted on supply chain performance assessment through case studies, surveys, and literature reviews. The studies recommend various methods to evaluate supply chain performance, including conceptual framework, quantitative models, and tools to select appropriate metrics and reveal a set of operational and financial metrics essential for monitoring and assessing the supply chain performance (Lu *et al.*, 2016). Performance measurement frameworks typically group these metrics under different competitive dimensions such as sustainability, responsiveness, effectiveness, and flexibility and define them within multiple perspectives like the customer, operations, finance, information technology, and environment (Adivar *et al.*, 2019).

A number of recent research studies focus on quantitative models to support the need for automated decision-making processes. These models, for example, apply artificial intelligence (AI) techniques to predict supply chain and logistics performance. Lima-Junior & Carpinetti (2020) proposed a performance prediction system based on the SCOR model and artificial neural networks. Sustainability management is vital to reaching supply chain objectives and logistics service effectiveness. It is critical to incorporate sustainability measures to determine sustainability performance in the supply chain. Various sustainability measurement approaches are being used in different industries. They address environmental issues to a considerable degree (Ahi and Searcy, 2015). It has been recognised that incorporating sustainability requirements into the standard supply chain performance model is challenging. Qorri et al. (2018) developed a conceptual framework for sustainability performance measurement by reviewing 104 papers. They found that the Fuzzy logic technique, DEA (Data Envelopment Analysis), AHP (Analytical Hierarchy Process), Balance Scorecard, and Life Cycle Assessment are the most commonly used methods. The SCOR model is applied as the structural basis in most of these techniques or is often used in combination with other performance measure methods (Sellitto *et al.*, 2015).

Measuring supply chain sustainability performance is essential to managing and guiding sustainability changes across collaborating organisations as it provides helpful data for decision-making at strategic, tactical, and operational levels. It becomes a difficult and intrinsically complicated process since sustainability performance assessment should evaluate social, environmental, and economic elements across all supply chain collaborators (Negri *et al.*, 2021). Supply chain sustainability performance aims to increase socioeconomic advantages while limiting negative environmental repercussions, which frequently leads to contradictory criteria in decision-making. Hence, evaluating supply chain sustainability performance is a multi-criteria decision-making problem, and fuzzy logic is an appropriate technique for incorporating uncertainty, intangibility, and ambiguity (Qorri *et al.*, 2022).

Big data capabilities in supply chain analytics are now expanding to the next level in supply chain transformation. Companies can access fresh information from big data about their customers' consumption patterns, product specifications, suppliers and customers, as well as overall market potential. Big data analytics has the advantage of being able to analyse and process data in the supply chain to increase its competitive edge (Thekkoote, 2022). A recent study used big data to validate the performance of service attributes and to understand the airline service quality, which had primarily been evaluated through survey techniques. To fulfil the research goal, 157,035 consumer records from website data were examined in total. One of the primary factors that directly influence passengers' choice of airline services has been identified as cost. Cost, however, is inadequate on its own to be chosen as a lasting competitive advantage. The research suggests that airlines should manage supply chain performance attributes in a way that passengers perceive as value for money to obtain a competitive advantage over their competitors. Because that onboard meal quality has a considerable impact on the performance of inflight services from the perspective of passengers, airline management needs to have a thorough awareness of other attributes of airline catering service delivery such as speed, timing, meal presentation, and varieties (Park *et al.*, 2020).

3.2.4 Supply Chain Practices and Evaluation

This section presents the literature that has been reviewed from the perspective of supply chain practices in organisations, their impact on supply chain performance and practice effectiveness assessment for supply chain organisations.

Many organisations have realised that supply chain management (SCM) is important in creating a sustainable advantage for their products and services in an increasingly competitive market. SCM integrates and maintains materials flow, information flow and financial flow among all parties in the supply chain (Bui *et al.*, 2021) to deliver the right product to the right place at the right time (Islam *et al.*, 2013). In SCM, it is recognised that parties in a supply chain can impact the performance of each other directly or indirectly, which could affect the overall effectiveness of the supply chain (Liu and Lee, 2018). SCM has a dual purpose of improving the performance of both the individual organisations in a supply chain and that of the entire supply chain towards increasing overall effectiveness. SCM strives for close integration of internal functions and relationships with external stakeholders such as suppliers and customers to be highly competitive and to increase profitability in the long term. This could be achieved through effectively adopting various supply chain practices. The general aspects of supply chain practices should be able to demonstrate the above dual purpose of supply chain management (Sundram *et al.*, 2011).

As organisations started to focus on enhancing the performance of the overall supply chain along with the organisation's performance, understanding and implementing supply chain management practices has become an essential requirement for remaining competitive in the global market and improving profitability. Organisations can produce significantly better process performance by managing their supply chain practices effectively. The literature describes supply chain practices from various perspectives, with the goal of improving performance. Supply chain practice is a specific way to configure a process or set of processes within an organisation to enhance the effectiveness of its supply chain (Georgise *et al.*, 2013). Li *et al.* (2006) describe the dimensions of supply chain practices, namely, strategic supplier partnership, customer relationship, level of information sharing, quality of information sharing, and postponement. They outlined the continuous evolution of supply chain practices, including electronic data interchange (EDI), outsourcing, excess inventory reduction, process flow, customer relationship and supplier partnership. Mahadevan *et al.* (2022) investigated supply chain performance in the context of collaborative supply chain practices. The research used an innovative approach by linking collaborative supply chain practices such as supply chain integration, information sharing, and supply chain visibility in measuring supply chain performance.

Researches provide empirical evidence about the relationship between supply chain practices and performance. Truong *et al.* (2017) have developed a conceptual model using supply chain practices, namely, process control and improvement, top management support, customer focus, and supplier management, to establish their relationship to the organisation’s operational performance. According to their research findings, these practices, directly and indirectly, impact operational performance. Other empirical evidence shows that customer relationship management, supplier relationship management, goal congruence, and information sharing positively influence supply chain performance and retail firms’ performance (Gandhi *et al.*, 2017). A study conducted by Sundram *et al.* (2011) describes the relationship between supply chain management practices and supply chain management performance within Malaysia’s electronic manufacturing industry. The research identifies seven constructs of supply chain practices: supplier strategic partnership, customer relationship, information sharing, information quality, postponement, agreed vision and goals, risk, and reward sharing.

A previous exploratory research study on supply chain management planning practices attempts to investigate the relationship between SCOR planning practices and supply chain performance (Lockamy and McCormack, 2004). The research was designed to find out the most important supply chain planning practices in four different decision areas of the SCOR model that relate to supply chain performance. These decision areas include plan, source, make, and deliver. The nine critical supply chain planning practices used in the research by Lockamy and McCormack (2004) are planning processes, collaboration, teaming, process measures, process credibility, process integration, IT support, process documentation, and process ownership. Their findings revealed that supply chain planning practices are necessary for all SCOR decision areas. They also called out the gap between recognising supply chain practices that are so important to supply chain performance and the implementation of the supply chain practice.

Many high-performing organisations mainly implement the best supply chain practices to get the desired results. Supply chain practices such as supplier collaboration, lean production, quality management, and customer focus are commonly used in manufacturing firms and substantially affect the firm's performance (AL-Shboul *et al.*, 2018). Zhou and Li (2020) surveyed 138 SMEs to explore the impact of supply chain and quality management practices on corporate business performance, mainly focused on market share performance and innovation performance. The results of the data analysis show that the exchange of information through the supply chain has a significant positive impact on supply chain practices which has substantial positive effects on both market share and innovation. The study also finds that supply chain information sharing plays a crucial role in supply chain management, enhancing effective supply chain practices and significantly impacting business performance. The findings also suggest that effective supply chain practices play an essential role in achieving corporate sustainability. Supply chain information sharing encourages a closer relationship between SMEs and their business partners, improving the firm's social and environmental sustainability. The improved level of supply chain integration is vital for enhancing supply chain practices. Supply chain integration facilitates fully or partially the relationship between supply chain management practices and supply chain performance (Kaliani Sundram *et al.*, 2016).

Sustainable supply chain management has become an increasingly popular area of research recently, as it is an essential driver of business performance. Green supply chain management practices can positively influence the organisation's environmental and operational performances. Supply chain practices such as building supply chain traceability and collaboration with eco-system partners will lead to better results for environmental sustainability and cost performance (Cousins *et al.*, 2019). Vijayvargy *et al.* (2017) identified five green supply chain management practices, namely, green purchasing, eco-design, customer environmental collaboration, investment recovery, and internal environmental management and found that adopting the practices can improve operational performance.

Many studies explored the relationship between supply chain practices and performance in a variety of contexts. Sukati *et al.* (2012) found that supply chain practices meaningfully correlate with supply chain performance. It has been discovered that social supply chain practices influence social sustainability performance (Awan, 2019). Nosratpour *et al.* (2018) examined the positive association of supply chain practices with organisational performance in the automotive industry. However, few studies have been conducted on the assessment of supply chain management practices. Li *et al.* (2006) proposed a framework to test the relationship between supply chain practices and organisation performance. The research findings suggest that a high level of supply chain practices can generate improved performance. Chardine-Baumann and Botta-Genoulaz (2014) proposed a framework to assess and analyse possible relationships between traditional supply chain management practices and their impact on performance. The model assesses the performance of supply chain practices by categorising a company's sustainable development into three dimensions: economic performance, environmental performance, and social performance.

Kozarević and Puška (2018) applied a methodology for measuring the influence of supply chain practice variables on supply chain performance in the food industry. They used a hybrid method based on the fuzzy set theory and the FTOPSIS method. The research was carried out in 135 food companies. The measurement of research variables was collected in the form of linguistics variables, which were subsequently transformed into crisp values. The research introduced a way of measuring supply chain practices and performance to confirm their relationship. Sari (2017) developed a multi-criteria decision framework for evaluating green supply chain management practices. That framework integrates Monte Carlo simulation, Analytical Hierarchy Process (AHP) and VIKOR methods in a fuzzy environment. They selected 18 green supply chain management practices in a hierarchical structure under four main supply chain areas: inbound operations, production operations, outbound operations, and reverse logistics for evaluation.

Espadinha-Cruz *et al.* (2011) presented a model for evaluating the overall interoperability of lean, agile, resilient and green practices in the automotive supply chain. They applied the AHP to the interoperability evaluation model, which was constructed based on the hierarchical structure. The use of AHP decision theory in this evaluation transforms subjective opinion into scores and reduces the dependency on human judgement. The proposed model helps to improve supply chain interoperability by analysing which practices will be adequate to apply in the supply chain.

Fornah and Pujawan (2020) proposed a framework for effective supply chain practices by assessing supply chain practices and how they impact supply chain performance. The framework uses supply chain paradigms, supply chain enablers and non-financial performance to assess the supply chain practices and their impact. The study's findings concluded that higher-level supply chain practices lead to better overall performance and improvement of the company. Mensah *et al.* (2014) examined supply chain practices and their influence on the performance of a company in Ghana. Their research focuses on practices related to supplier collaboration and customer relationships. Their findings ascertain that the supply chain practices have a significant, positive influence on the company's business performance.

Islam et al. (2018) used a hybrid approach to identify critical Green Supply Chain Practices (GSCP) based on importance and performance and suggested 34 attributes for evaluating GSCP in the leather industry. Fuzzy set theory was used to control the lack of clarity in human perception based on the characteristics of GSCP. The fuzzy importance and performance analysis (FIPA) matrix was developed for the determination of critical GSCPs as an enabler for improving environmental performance. They used mean values of importance and performance attributes to design a plot for four quadrants to differentiate the priority level. Their findings revealed that the leather industry's most critical green supply chain practices are minimising waste during manufacturing, designing for recycling water, selecting green suppliers based on environmental criteria, and participation in ISO 14001 environmental management system. Zhu *et al.* (2008) investigated a scale for assessing green supply chain management practice implementation in the manufacturing industry. They collected data from 341 Chinese manufacturers to test the construct and validate the measurement scale. The results suggest that all 21 measurement items for green supply chain management (GSCM) practice implementation used in the evaluation are critical attributes of five implementation factors: internal environmental management, green purchasing, cooperation with customers, eco-design, and investment recovery.

The effectiveness of a supply chain practice can be varied by the organisation. Whether a practice is effective or not should be answered by the organisations that use the practice. The effectiveness of the practice is likely to determine its effect on related results (Guest and Conway, 2011). In this thesis, practice effectiveness entails how well the supply chain practices are successful in achieving the desired performance outcome as perceived by the organisation. The practice may not be implemented or perform well in one organisation, or the expected performance outcome may not be much important for that organisation compared to other performance attributes. A methodology is required to assess the level of effectiveness of supply chain practices and to define whether they are or are not relevant to the organisation and whether their effectiveness level is appropriate or not for the performance expectation (Sellitto, 2018).

3.3 Effects of COVID-19

The COVID-19 pandemic has threatened and caused critical concern for the global supply chains, including those of airline catering businesses. This unprecedented challenge has deeply impacted the business environment and health care systems around the world. As the supply chain is the backbone of many production and service operations, academic researchers and practitioners have been challenged to explore strategies to mitigate the imminent disruptions in both upstream and downstream supply chains. Unique supply chain disruptions like the COVID-19 outbreak are low-frequency, high-impact events that cause failure in one or more supply chain nodes and can lead to the unavailability of services or goods (Kumar *et al.*, 2018). Disruptive events provide an opportunity to learn from their effects, and learning from the COVID-19 pandemic can improve future performance management and decision-making during supply chain disruptions (Remko, 2020).

COVID-19 has rapidly spread globally since it emerged in 2019. Governments worldwide instituted extensive safety plans such as wearing masks, social distancing, national lockdowns, and border restrictions to control the pandemic growth and manage health system resilience. These measures result in a negative impact on international trade and cause disruption in the global supply chain. Manufacturing sectors such as the automotive, pharmaceuticals and electronics industries and service sectors like airline and healthcare heavily depend on international supply chain partners. These supply chains have been substantially impacted due to the COVID-19 outbreak (Belhadi *et al.*, 2021). Initially, it created direct and immense supply disruptions, and then the economic declines in demand along with companies' investment concerns due to uncertainties created demand disruptions. These disruptions in supply and demand would not be uniform across companies and industries. The effect of COVID-19 on the different business sectors will be different due to the dissimilarities in demand and supply patterns (Sharma *et al.*, 2020).

Disease outbreaks such as the COVID-19 pandemic significantly adversely impact businesses and supply chains, including dropping their efficiency and performance (Guan *et al.*, 2020). Business resilience and sustainability have been affected by the proliferation of COVID-19 disruptions across the supply chains (Ivanov and Dolgui, 2021). Unlike previous disease outbreaks in the recent past, this pandemic has affected all nodes and links in a supply chain at the same time. As a result, the flow of products through the supply chain has been severely disrupted. COVID-19 initially hit China, which is at the core of many global value chains and disrupted the supply chain (Luo and Tsang, 2020). The global supply chain has experienced several disruptions in the past; most recently, it was disrupted by a huge financial crisis during 2008-2009. But, the ongoing COVID-19 pandemic is unique. While the lessons learned from previous events would be useful today, there are some differences in their nature. At that time, it was more of a demand aspect disruption than a supply, whereas the COVID-19 pandemic has had a significant impact on both supply and demand (Goel *et al.*, 2021). On the demand side, global demand continues to decline as the lockdown continues and physical consumer spending reduces. The effects of COVID-19 on supply and demand are already shown in global oil prices (Fernandes, 2020). The global oil demand has fallen significantly during the pandemic due to the worldwide lockdown and other factors related to COVID-19. Many suppliers and manufacturers have planned to reduce or even stop some production as demand declines (Goel *et al.*, 2021).

There is an increasing number of studies on the overall risk of the COVID-19 pandemic (Nakamura and Managi, 2020). For example, Wu *et al*. (2020) analysed the risk of transmission from international flights compared to local flights. Another study predicted the impact of travel limitations on the domestic and global spread of COVID-19 (Chinazzi *et al.*, 2020). Nakamura and Managi (2020) measured the importation and exportation risk of COVID-19 and suggested undertaking strict airport countermeasures. It's absolutely critical to understand the short-term and long-term effects and conduct adequate risk assessments during black swan incidents like the COVID-19 outbreak. In this way, organisations can determine the appropriate response and mitigation strategies and define performance measures (Kochan and Nowicki, 2018). So far, the uncertainties and subjectivities associated with the effects of the COVID-19 pandemic on the supply chain have made it difficult to fully define risk scenarios and establish effective response strategies for the long term (Ivanov and Dolgui, 2020).

A report previously published in Fortune magazine in February 2020, before the COVID-19 outbreak was classified as a pandemic in March 2020, found that 94% of Fortune 1000 companies experienced disruptions in their supply chains due to COVID-19 infectious disease (Chowdhury et al., 2021). A recent survey about the impact of COVID-19 conducted on 558 manufacturing companies in the U.S. discovered that more than 78% of companies expected severe economic effects from the uncertainty in their activities caused by the pandemic (Belhadi et al., 2021). Major business enterprises such as automotive companies and retailers have been cutting jobs as sales fall due to the ongoing pandemic. The government's lockdown restrictions have forced the closure of several factories and shops. Potential buyers locked themselves in the house for a longer period, and there has been a significant shift in consumer behaviour during this period of uncertainty (Ramanathan *et al.*, 2021).

Although the extent and cost of this pandemic are not yet known, we know that service sectors that are heavily dependent on movements, such as airlines and travel, were significantly affected, and recovery would be very slow. The airline industry has faced many troubles throughout history, but no one seems as serious as the one caused by the spread of COVID-19 (Amankwah-Amoah, 2020). Though airline passenger traffic was forecasted with an increasing trend earlier, the airline industry is almost grounded by COVID-19, and the recovery has slowed in most markets due to travel restrictions (Albers and Rundshagen, 2020). Unlike the previous crisis, it is recognised as the most significant decline since World War II, as shown in Figure 3.2. This has a significant impact on airline catering service organisations, and their operations have been severely affected. The COVID-19 crisis is longer and deeper than anyone would have expected. The airline workers bear the brunt of COVID-19 volatility, sales declines and uncertainties. The airline industry has seen considerable work losses of almost 7-13% (Sobieralski, 2020). According to a recent estimate, over 400,000 aviation workers were being furloughed or laid off because of continuing disruption. Many of the world's largest airlines have announced plans to conduct mass job cuts and introduced unpaid leave schemes (Belhadi *et al.*, 2021). A recent press release from IATA estimated a net airline industry loss of $126.4 billion in 2020. IATA represents 290 airlines, including 82% of worldwide air traffic. It recognised that the losses would decrease from 2020, but the pain of the crisis would increase (IATA, 2021).

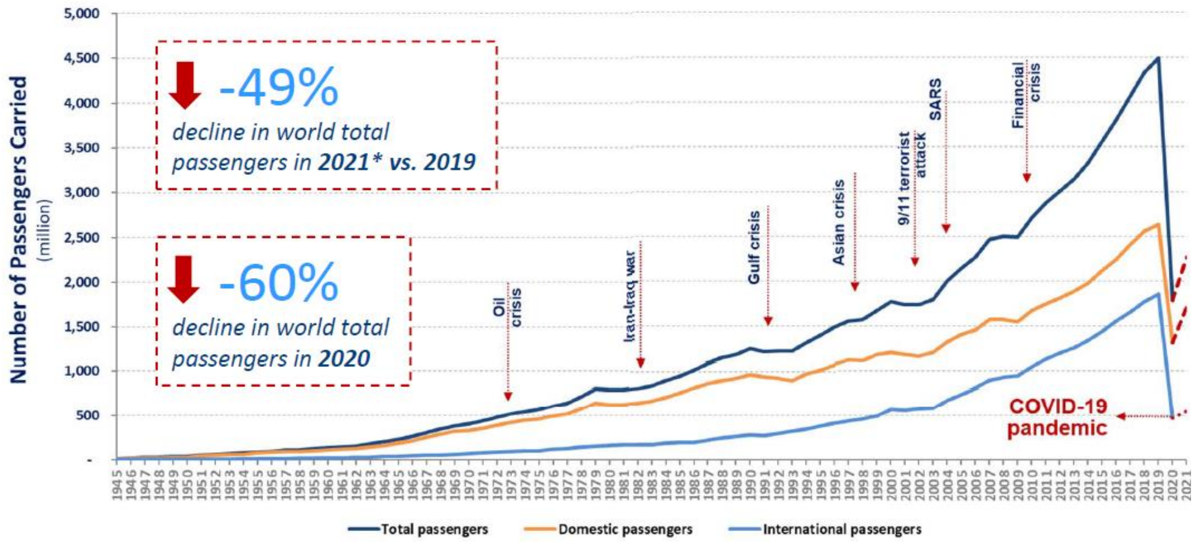


Figure 3.2 World passenger traffic evolution 1945 – 2021 (ICAO, 2021)

Experts estimate that restoring the airline sector back to normal stage would take four to six years (Sobieralski, 2020). In the face of the ongoing crisis, IATA recognised that the airline sector would begin to recover by the end of 2021. The latest pandemic surge, fuelled by the new variant of COVID-19, Omicron is likely to deteriorate the recovery of aviation and related sectors like airline catering. Governments need to put plans in place to restart the industry without further delay when the pandemic situation allows the borders to be reopened. IATA has reported that a substantial share of the $ 3.5 trillion in GDP and 88 million airlines supported jobs are at risk during the pandemic (IATA, 2021). The actual restart of the airline industry will revitalise the travel and tourism sectors and the economy in general (IATA, 2021). Due to flight cancellations and airport closures, economic losses are likely to force many airlines to look for innovative solutions and new performance measurement systems to survive and thrive.

In fact, COVID-related policies of operating social distance measures have an impact on pricing strategy. Many of the major airlines have already introduced some elements of inflight social distancing by not allowing passengers in the middle seats and letting them switch seats if they have any health concerns. Furthermore, some airlines have limited in-flight meals to reduce contact between the cabin crew onboard and the passengers. Other airlines have introduced more disposable catering containers and supplied refreshments and meals for passengers on board by putting the prepacked meal box on the seats. It is likely that low prices are hard to come by, especially for low-cost airlines that compete with the prices by operating high-density seating and selling buy-on-board meals. However, today's airlines have little or no choice but to reduce their flight operations as a result of border restrictions, fear of infection, and long quarantine period. IATA data shows that the pandemic occurrence resulted in a sharp drop in airline share prices. This is expected to have a substantial impact on shareholders and the capital value of the global aviation industry (Dube *et al.*, 2021).

People are reluctant to travel during the COVID-19 pandemic period due to health and safety concerns arising from the pandemic. Airlines must ensure passengers' safety as this would encourage the public to want to travel again. Many different strategies are being adopted by major airlines to assure passengers' comfort, health, and safety. Some of these are wearing a surgical face mask, providing a health care kit and hand sanitiser in the gate area before onboarding, personnel protective equipment (PPE) for cabin crew, keeping the middle seat empty, temperature check of passengers before onboard, COVID-19 test before travel, using electrostatic spray disinfectant technology, and cabin baggage restrictions (Dube *et al.*, 2021).

Sustainability is a serious issue that requires the airline sector's attention worldwide (Dube and Nhamo, 2019). Focusing on environmental sustainability becomes harder for some businesses in the short term due to the financial pressures and threats to the company's survival caused by the COVID-19 pandemic. This limits the scope of management and companies to respond to environmental problems. Some environmentalists and activists have suggested that many industries, including airlines, use the pandemic to give up or further delay implementing organisational measures into the climate change programme (Amankwah-Amoah, 2020). In this COVID-19 situation, airlines can no longer rely alone on environmental pledges for market competition but also need to ensure additional health and safety measures in protecting their passengers' health by avoiding possible viral infections in their in-flight service facilities. Therefore, setting a healthy environment has emerged as a key factor of competitive advantage for airlines. To lower COVID-19 effects and attract lasting success, airline managers and executives need to be innovative in ways to offer healthy assurance of service to passengers.

In addition, the COVID-19 pandemic disruption in the airline sector has had a significant impact on several other dependent industries, such as aircraft manufacturing, hotel, tourism and airline catering businesses (Martin *et al.*, 2020). It is important to study the airline catering industry's performance measures considerations, and strategies during the COVID-19 pandemic, especially regarding managing airline catering supply chains in a crisis.

3.4 Research Gap

The airline catering business sector is facing a rapidly evolving and potentially disruptive set of business transformations, and the supply chain is an essential part of it. Conversely, the review of the existing state of the knowledge about supply chain performance and practices in the airline catering industry sector could only find very little research into this area. Some of the existing research studies provide helpful information regarding the general business aspects of airline catering functions. However, an in-depth analysis needs to be examined to understand the complexity of its supply chain and operational processes. There are only a few studies on implementing the SCOR model for the airline catering supply chain, an emerging and important research area in the travel, tourism and aviation industry. In the airline catering supply chain literature, research studies investigate, for example, the strategies that strengthen the organisation's competitive position (Sundarakani *et al.*, 2018). But, there are no studies covering the aspects of supply chain performance measures concerning emergencies such as the COVID-19 pandemic according to the dynamic of the aviation environment and airline catering service requirements. Further research is needed to analyse supply chain processes and logistics service performance and explore how performance metrics can be adapted in uncertain times.

Moreover, there is a dearth of evaluation methods for measuring how airline catering supply chain practices are performing and which practices have a high-level contribution toward overall supply chain practice effectiveness. Previous empirical research and evaluations show that supply chain practices contribute to the organisation's business and supply chain performance. Further studies are required on measuring the effectiveness of supply chain practices. Regarding the airline catering industry, there is a need to develop a SCOR-based approach for evaluating supply chain practice effectiveness to fill the existing knowledge gap in the airline catering supply chain literature, which motivated this research.

Additionally, the importance of enterprise systems in achieving improved supply chain efficiency continues to evolve with the introduction of cloud computing. Use of technology is one of the most important metrics for measuring the performance of supply chain collaboration, alongside other metrics such as flexibility and responsiveness (Ramanathan *et al.*, 2011). Yet, the reality in some industries like airline catering is that the supply chain systems and technologies that support their business functions are often designed poorly or unable to work collaboratively as a sustainable and scalable application. Airline catering organisations alike recognise the need to develop architecture and process models for more systematically implementing logistics execution systems. More research is needed to analyse the feasibility of integrating logistics business processes in the airline catering supply chain and develop a solution design for the integrated logistics execution.

3.5 Chapter Summary

This chapter reviews the research on supply chain management processes, performance, and practices. It describes the supply chain operations reference (SCOR) model, as well as its concepts, organisational structure, and areas of application in various industry sectors that have been covered in previous studies. The chapter discusses using information systems to leverage business process management, as well as aligning systems with business processes through reengineering and customisation. It demonstrates the impact of supply chain practices on supply chain performance, as well as various methodologies for measuring practice effectiveness presented in the existing literature. It then discusses the impact of the COVID-19 pandemic on the supply chain, including disruptions, challenges, and trends. Finally, this chapter highlights the research gap for implementing the SCOR model in the airline catering industry.

4 Research Methodology

4.1 Introduction

The methodology is essential for conducting research because it defines how a researcher plans and executes the study of the chosen research theme (Silverman, 2013). Through three projects, this research focuses on three aspects of the airline catering supply chain: processes, performance, and practices. This study combines academic knowledge of the SCOR model with industry best practices to develop solutions. It is based on a combination of a literature review in the SCOR model, supply chain performance, practice areas, and a case study conducted at an airline catering supply chain company in the UK. The purpose of this research is to look into the research objectives described in the introduction section in order to better understand airline catering business processes, develop performance metrics, and provide a framework for evaluating practice effectiveness in the airline catering supply chain. This research employs an investigative research approach to assist the researcher in developing a deeper understanding of the business need. This research is based on a single case study that includes a thorough investigation of supply chain and logistics processes in the airline catering business environment. This case study investigates the airline catering industry's performance considerations and understanding of supply chain practice effectiveness.

Research methodology provides the philosophical framework for the research. This chapter of the thesis describes the research process, research philosophy used in this research, research methods, data collection and analysis approaches used throughout the research, and explains the researcher's choices by outlining the benefits and drawbacks of the approaches while keeping practical applicability to this case study research in mind.

4.2 Research Process

Research is the process of developing a solution or reaching a conclusion through a series of clearly defined steps of collecting, analysing, and interpreting planned and systematic data (Crano *et al.*, 2015). Scientific research process defines when the problem is recognised, data is collected, a solution or hypothesis is formed based on the data and the solution or hypothesis is validated (Coolican, 2014). It was essential to design an adequate research process to investigate the existing issue. To further explain this definition, several steps of the research process followed in this research are shown in Figure 4.1.

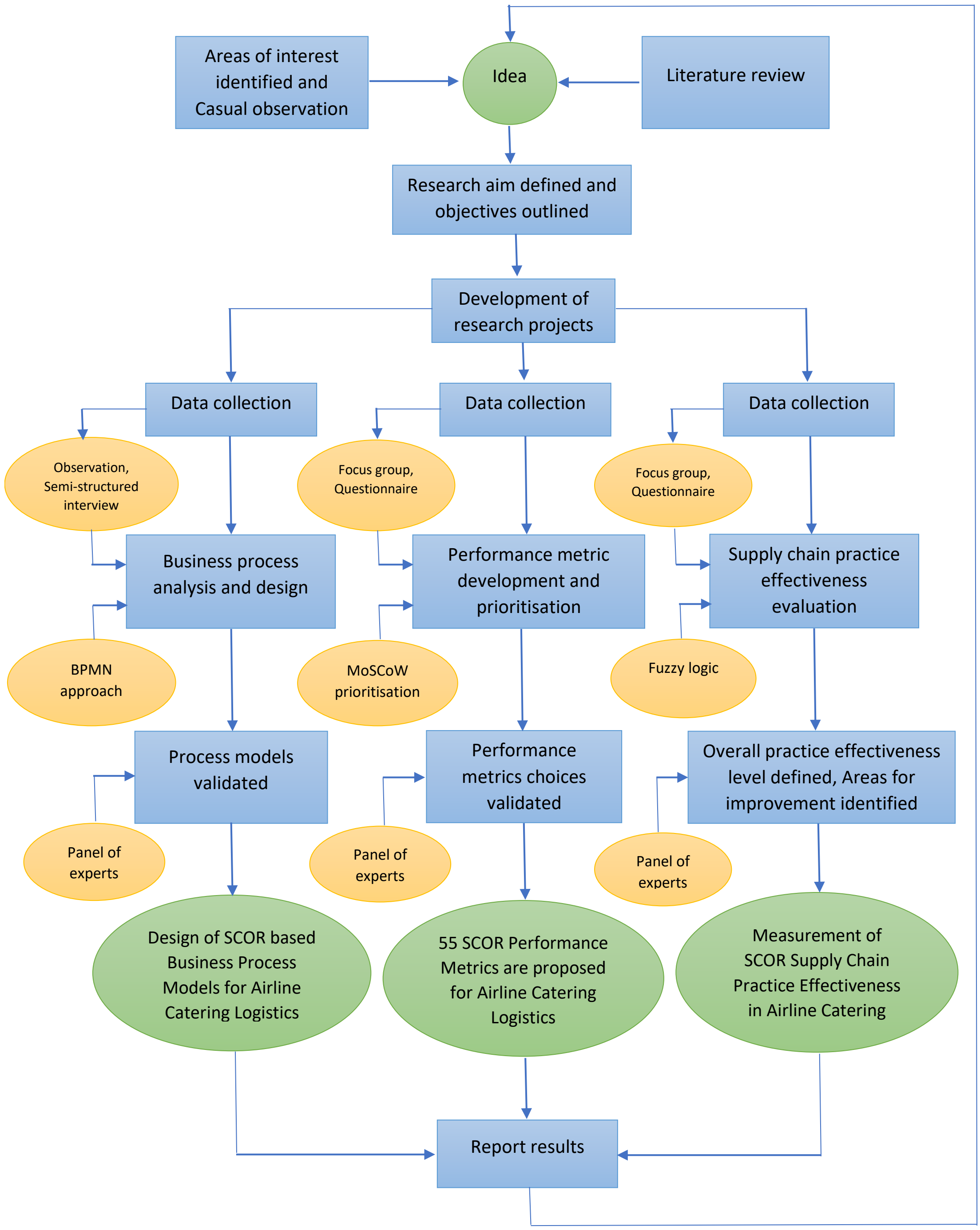


Figure 4.1 Research process

The investigatory research began with the selection of airline catering supply chains as areas of interest. First, the idea was formulated during the preparatory stage of the research through a review of the literature and casual observation of the airline catering supply chain operations. This process involved iterative revisions of the original research interest until the gaps in the airline catering supply chain research area were uncovered. The industry challenges prompted several prospective research questions. To see if such questions had been addressed, the literature was thoroughly reviewed. Based on the final list of research problems, the research aim of improving airline catering supply chain effectiveness was defined, and the research objectives were formed from the research aim, which was then improved multiple times. The research objectives were then used to develop three key projects to achieve the research aim. The first project was the design of business processes, the second was the development of performance metrics, and the third was the evaluation of practice effectiveness. The literature was then explored further to establish an acceptable theory to achieve the project's goals. The key concepts and previous work on the research topic were determined. The literature review focused on a number of areas in accordance with project topics. Firstly, the airline catering supply chain was considered, then supply chain performance measures and supply chain operations reference model were explored, and finally, supply chain practices and evaluation were focused on.

Defining the appropriate research strategy requires careful consideration of different research methods to determine the design that best fits each research project and corresponds to the researcher's point of view. For each research project, appropriate data collection and analysis methods were used. To understand the current processes, data were first gathered through process observation and interviews with subject matter experts for the process modelling project. Semi-structured interviews were conducted with key supply chain professionals from the case study organisation in the airline catering supply chain sector. The AS-IS situation was then analysed using SIPOC diagrams. Following that, detailed process mapping and analysis were performed using the BPMN method. An appropriate team of experts examined and validated business process models.

The data for the performance metrics development project was gathered using a qualitative approach, with questionnaires serving as the primary data collection method, supplemented by a focus group. First, the airline catering SCOR model was developed after observing the operational process in an airline catering organisation and reviewing relevant literature and well-known SCOR frameworks. Second, as a result of the preceding process, a set of 55 performance metrics associated with various performance attributes and processes suitable for use in airline catering organisations evolved. A selected panel of experts examined and validated performance metrics in order to understand their applicability and gather feedback on performance consideration changes during the COVID-19 pandemic, as well as metrics choices using the MoSCoW prioritisation method.

Finally, during the third project of the research, a conceptual model for supply chain practice effectiveness assessment was developed, which included various levels of practice effectiveness factors. The fuzzy logic approach was used in the effectiveness assessment. The proposed conceptual practice effectiveness assessment model was then applied to the case study organisation to determine the overall level of practice effectiveness and to identify areas for improvement. A panel of experts were formed as a focus group. The data on performance rating and the importance weights of practice effectiveness (PE) factors were obtained from the panel using questionnaires. The linguistics variable values from questionnaire data were converted into appropriate fuzzy numbers, which then were used to calculate the overall practice effectiveness level of the airline catering supply chain organisation. All three projects are covered in the main chapters of this thesis, and their findings are documented.

4.3 Research Philosophy

It is well acknowledged that philosophies have a vital, albeit sometimes ambiguous, relationship with research. The broad term 'research philosophy' refers to both the evolution of knowledge and the nature of that knowledge. When we conduct research, we are broadening our understanding of a particular subject. Important assumptions about the researcher's worldview are embedded in the research philosophy chosen for study. These assumptions will form the basis for the research plan and methodologies (Saunders *et al.*, 2012). A research philosophy is a set of beliefs that govern how data about a research topic should be collected, analysed, and applied. It is concerned with the origin, nature, and creation of knowledge. Addressing research philosophy in the dissertation essentially entails recognising and articulating the researcher's own ideas and assumptions. As indicated in Figure 4.2, the identification of research philosophy is positioned in the outer layer of the ‘research onion’.

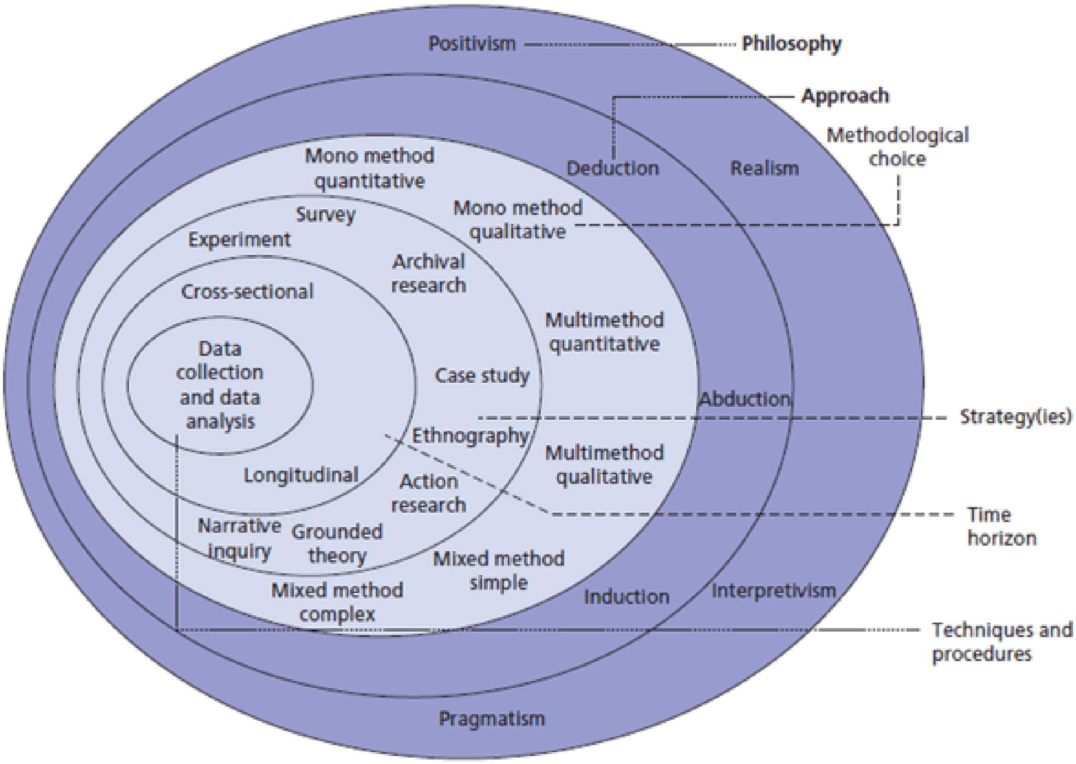


Figure 4.2 The research 'Onion' (Tsang, 2016)

According to Creswell (2014) and Guba (1990), While various classifications are used to differentiate research paradigms, the majority of them focus on three core features: ontology, epistemology, and methodology. Ontology is concerned with the nature of reality in the physical world, whereas the epistemology assumption is concerned with how knowledge is generated in order to comprehend the nature of reality. Finally, methodology refers to the rationales underlying the procedures employed to investigate what is thought to be knowable. Therefore, the conclusions of this case study research are influenced by the researcher's perception of reality and his interactions with subject matter experts in the organisation who shared information about business process integration operational concerns, supply chain performance, and supply chain practices in the airline catering supply chain. Several research philosophies can be used to shape the research design for supply chain management studies. Each research project of this study can be placed in relation to the main research philosophies.

There are various types of philosophies associated with various disciplines. The four major philosophical research perspectives are pragmatism, positivism, realism, and interpretivism. Pragmatism research philosophy acknowledges that there are numerous ways to perceive the world and conduct research, that no single point of view can ever provide an accurate picture, and that multiple realities may exist (Saunders *et al.*, 2012). Positivism is a philosophical school of thought that holds that only "factual" information obtained through observation, including measurement, is reliable. In positivist studies, the researcher's role is limited to data collection and unbiased interpretation. In other words, the researchers conduct the study as objective analysts who are divorced from their personal values. The findings of these types of studies are usually observable and measurable. The realism research philosophy holds that reality is distinct from the human mind. This philosophy is based on the assumption that knowledge is developed scientifically. The two types of realism are direct and critical realism. The interpretivism philosophy requires researchers to interpret research materials in order to incorporate human interest into a study. As a result, interpretive scholars believe that only social constructs like language, consciousness, and shared meanings provide access to reality.

Furthermore, each research philosophy is linked to prominent data collection methodologies, as shown in Table 4.1 below.

Table 4.1 Research Philosophies and popular data collection methods (Saunders *et al.*, 2012)

Pragmatism	**Positivism**	**Realism**	**Interpretivism**
Mixed methods, multiple method designs, quantitative and qualitative data collection methods.	Highly structured data, large samples, measurements, quantitative analysis, can adopt qualitative methods	Qualitative or quantitative data collection methods, choice of methods must fit the subject area	Small samples, in-depth analysis, qualitative analysis, investigations

The research philosophy chosen is influenced by the practical implications of the research. There are significant philosophical differences between research studies that focus on facts and figures, such as evaluating the effectiveness of airline catering supply chain practices, and qualitative studies, such as an analysis of airline catering supply chain performance considerations during the COVID-19. For example, the process design project takes an interpretivism philosophical perspective, whereas the performance metrics development research reflects realism philosophical concepts. Interpretivism was used to understand the research phenomenon, reflect the study's context, consider the inherent complexities in airline catering supply chain processes, and the subjective nature of the realities associated with the experiences of subject matter experts (SME). Interpretivism interprets the phenomena in their context and has the ability to utilize how the participants develop their knowledge (Schwandt, 1994).

The relevance of an interpretative approach is determined by its ability to comprehend the subjective nature and multiple interpretations of reality expressed by participants who are SMEs in various functional areas of airline catering logistics operations. Based on their operational experiences, it was planned to understand how SMEs perceive process flows and the impact of one process execution on others in this context. Freedom of expression and flexibility based on the opinions of the participants during the process modelling stage justify the relevance of this interpretivism approach in developing the business process design framework.

For the performance metrics development study, critical realism is the most relevant and it was used as the research paradigm to shape this study of performance measurement in airline catering service. Scientific realism is the belief that theories describe real-world phenomena (Saunders *et al.*, 2012). The performance metrics development research acknowledges the importance of multi-level research, such as at the individual supply chain practitioner and focus group levels. Each of these levels has the potential to change the researcher's perspective on the subject under investigation. The critical realist's view of an ever-changing social environment is much more in line with the goal of business and management research, which is all too often to understand the causes of phenomena before making recommendations for change. This project examined how supply chain performance considerations changed during the pandemic. Before reaching a conclusion, the focus group discussed and deliberated on aggregated results from the personnel perspective of supply chain professionals.

The research philosophy used in the study of supply chain practice effectiveness reflects positivism principles. Only phenomena witnessed by researchers will result in the generation of credible data (Saunders *et al.*, 2012). Positivism is based on observable data that can be numerically analysed. It has dominated business and management research for decades. Crowther and Lancaster (2008) suggest that positivist research, on the whole, takes a deductive methodology. For this practice effectiveness study, researcher used existing theories of fuzzy logic and linguistic variables to build the evaluation model in order to develop a research strategy for collecting data on the performance and importance levels of supply chain practices used in the airline catering organisation. The researcher was independent of this study during the whole practice effectiveness evaluation process (Wilson, 2010). The study's goal was to explain and determine the overall practice effectiveness level of the organisation. Researcher engaged with the research participants as little as possible while conducting the study, and the overall practice effectiveness level and related measurements were entirely based on the facts provided by the participants.

4.4 Research Methods

According to Silverman (2013), it is critical to explicitly define the research approach, as well as the relevant concepts, theories, techniques, and methods, before doing research. First and foremost, the research approach gives a framework for how we view reality. Research methods are the tools we use to conduct research in a more comfortable and efficient manner. The key elements of the research methods are data collection and data analysis. This study contributes to the development of an appropriate solution for airline catering service execution by combining the research analysis of three areas: supply chain process, performance, and airline catering supply chain practices. This research study is based on the SCOR model and is tailored to the needs of the airline catering industry.

There are two types of research approaches in social research, such as this study, that are linked to the research methods used. They are known as quantitative and qualitative research approaches among researchers. Although there are differences between quantitative and qualitative research methods, both have their pros and disadvantages in how they perceive the world. They vary greatly and are influenced by a variety of factors, including study topics, research paradigms, and procedures. They must, above all, advance the aims and objectives of the study. Common sense aids in the selection of the appropriate approaches when a problem is typically either quantitative or qualitative in nature.

In this study, both qualitative and quantitative research methods were used. This mixed-methods approach is consistent with the study's philosophical position. In this study, the qualitative method is related to the qualitative understanding of the research scenario. It is concerned with determining the root causes of a specific problem. It is based on a small sample size rather than statistical data. In this study, the quantitative method is used to convert abstract concepts, such as performance and importance of supply chain practices, into quantifiable measurements using operational definitions.

4.4.1 Quantitative Research

The quantitative technique yields wide findings. This method has been defined as including the acquisition of numerical data; having a deductive perspective of the link between theory and research; preferring a natural science approach; and having an objectivist notion of social reality (Bryman, 2016). This type of research is the most conventional method of investigation. There is no room for researcher bias in quantitative techniques. Quantitative research focuses on the measurement and study of casual associations among variables rather than processes.

Quantitative research approaches use statistics and mathematics to describe and measure the frequency of events. Furthermore, "how many?" and "how often?" are frequently questioned in quantitative investigations. Quantitative data collection approaches, on the other hand, are based on numbers and mathematical calculations. Quantitative research is defined as the collection of numerical data and the expression of a deductive perspective of the relationship between theory and research (Bryman and Bell, 2015). In other words, quantitative studies use statistical approaches to investigate correlations between numerically recorded variables. Random sampling and structured data gathering tools are used in quantitative data collection approaches. Quantitative research findings are usually simple to present, summarise, and interpret.

The quantitative method tends to be based on positivism and seeks to establish a general cause-effect relationship to solving a social problem by linking abstract ideas of the relationship to precise measurement of the social world (Neuman, 2014). A quantitative method may be helpful for academics interested in determining the relative relevance of various sources of social phenomena (Bryman, 2016). Quantitative researchers think that by doing so, they would be able to assess the links between variables of phenomena and completely comprehend the existing correlations. Because statistical processes describe findings, conclusions may be generalised to the entire population of the sample studied. The term "quantitative approach" has come to refer to the methodology used in randomised experiments, quasi experiments, multivariate statistical analysis, and sample surveys (Creswell, 2003).

The goal of the practice effectiveness study was to identify performance-importance relationships between supply chain practices and performance attributes associated with supply chain practice effectiveness factors in airline catering service. Therefore, this quantitative approach was deemed suitable for the purpose of this study. Furthermore, a quantitative method was seen to be much more appropriate for this study because the goal was to get in-depth insights in a natural environment, based on understanding the entirety of airline catering supply chain requirements and case study organisation circumstances, and there was a strong desire to pursue representativeness.

4.4.2 Qualitative Research

Qualitative research is a form of investigation that aims to provide an in-depth examination of social phenomena in their natural environment and context (Klenke et al., 2016). Researchers who use quantitative methods have frequently criticised qualitative research. It has, nevertheless, garnered widespread acceptance, provided that data collection and analysis are carried out in accordance with the principles of the relevant qualitative research technique (Goulding, 2002). Qualitative research is frequently inductive, employs theoretical sampling, and is dependent on the researchers' viewpoints and data interpretation (Edwards and Holland, 2013). These characteristics distinguish it mostly from quantitative research. This study focused on how logistics processes are performed at the airline catering service centre, how performance considerations have changed during the COVID-19 pandemic, how effective their supply chain practises are in meeting their performance expectations, why business process integration is required for effective airline catering logistics execution, and why organisations prioritise certain performance metrics over others during the COVID-19 pandemic. This involved constant interaction between the researcher and the case study airline catering organisation.

The qualitative method enables researchers to collect data about "respondent perceptions in the context of their setting, through a process of attentiveness and empathetic understanding" (Miles and Huberman, 1994). It aids in the collection of comprehensive data, typically from small groups of individuals, through interactions between the researcher and respondents. The aim of most qualitative research studies is not to generalise but to provide a complete contextual understanding of an aspect of the human experience through in-depth study (Silverman, 2013). This explanation reflects what the researcher did when the qualitative approach was used in this study, and the phenomenon was studied and discussed from different data sources. This ensures that the research problem is not approached from a single lens but from different perspectives that have discovered and understood different aspects of the phenomenon (Mason, 2017).

The qualitative method, according to Denzin and Lincoln, (2008), is difficult to characterise precisely. It does not have a specific theory or paradigm of its own, nor does qualitative research have a distinct set of techniques or practices of its own. An interpretive, naturalistic approach to the world is used in qualitative research. In this research, researcher investigates airline catering supply chain in their operational settings, attempting to make sense of or interpret airline catering supply chain characteristics in terms of the meanings that supply chain practitioners assign to them. Researcher was interested in the airline catering industry perspectives of supply chain practitioners as well as the interpretations of subject matter experts of the case study organisation about their supply chain effectiveness. A qualitative technique is seen to be more suitable for process design and supply chain performance study's objectives. As this was an interpretive examination of business process integration difficulties or problems, a qualitative research technique was used, with the researcher at the centre of the interpretation. A qualitative approach to inquiry was chosen for the performance metrics development study as the researcher believes that supply chain practitioners’ knowledge, opinions, understandings, interpretations, experiences, and interactions are significant components of airline catering supply chain reality that their research objectives are intended to investigate (Mason, 2017). The study looked at airline caterers' perspectives on supply chain operations and supply chain performance.

4.5 Case Study Approach

For industry-focused research, case studies are a popular research method (Starman, 2013). There are several important reasons to use a case study. Case studies, for example, allow the researcher to investigate and comprehend complex issues. It can accommodate a wide range of philosophical perspectives. One of the benefits of this research method is its ability to capture the complexities of business situations; thus, it supports an in-depth study of the selected phenomenon. The case study method is more applicable when research questions aim to describe some current circumstance. The method is also useful when the research questions necessitate a detailed and in-depth investigation of a social phenomena (Yin, 2009). According to the research design, the case study research method used in this study is an investigative case study. The case study conducted in this research aimed at investigating the airline catering supply chain's business processes, performance considerations, supply chain practices, and effectiveness in the airline catering business environment at the case study organisation. The case study was conducted by the researcher in an airline catering service organisation in the UK that provides catering services for short-haul, mid-haul, and long-haul flights. Furthermore, for research ethics reasons, the name and references of this participating organisation have been omitted in order to respect the case study organisation's confidentiality rights. The case study organisation was chosen based on the criterion that it is a representative of the key industrial sector of the airline catering supply chain industry in the UK. The practical viability of access to the case study organisation also influenced the selection of case study.

A fundamental issue in conducting case studies is determining the unit of analysis (Yin, 2009). This case study research has been performed with airline catering supply chain management characteristics as unit of analysis. Three research studies explored three aspects of the airline catering supply chain: processes, performance metrics, and supply chain practices which are defined as embedded units of analysis in this research.

A case study is an empirical study that investigates a phenomenon in its real-world context, particularly when the lines between phenomenon and context are blurred (Creswell, 2014). For this reason, the study was carried out in a real-world setting with participants. It entailed communicating with supply chain practitioners, and subject matter experts to obtain a basic understanding of the logistics and supply chain processes in airline catering service. It was the first step in acquiring a fresh viewpoint and conducting research by immersing researcher in the field of airline catering supply chain to gain an initial understanding of the business operations. Data collected in real-world business settings, such as airline catering service centres and warehouses, made the context of their reality more understandable and convincing. This provided the detailed information required to accomplish research objectives and gain knowledge. The case study conducted in this research involved fieldwork. The researcher went to the shop floor and relevant departments in the business units to observe and document the operations functions in the natural airline catering business environment. In this case study, a mixed research method approach is used to collect both qualitative and quantitative data. The focus group research method is primarily used to explore and construct knowledge about the airline catering business. In this research, these research methods are supplemented by three additional data collection methods: observation, interviews, and questionnaires.

Initial research adopts a qualitative case study approach to analyse the current state of business functions. Some aspects of the research projects, such as practice effectiveness assessment, have used a quantitative approach. This research study captured best practices in the airline catering supply chain and current operational processes by focusing on the airline catering industry through an investigation. The data required for the current state business process analysis have been collected through participant observations and a few focus group sessions with business stakeholders, including shift operations managers, senior operations managers, IT manager, and site process improvement champion who validated the collected data. These business stakeholders were chosen for their functional expertise. These sessions aided in outlining current processes, performance measures, practices, and opportunities that had not been reviewed in a long time. The detailed requirements analysis process was carried out to understand the specific needs of the business by interviewing staff from various departments, such as the operations team and the planning team. To gain more insights, the research design in this study includes participant observation of current logistics practices. This observation enabled the researcher to conduct additional functional requirements gathering to perform detailed process mapping. The researcher gathered information about airline catering logistics processes, as well as current performance measures and supply chain practices, using a variety of data collection techniques. They are observation, field notes, interviews and questionnaires.

4.6 Focus Group

A focus group is a strategy that involves the utilisation of in-depth group discussions. Participants in this form of research are chosen based on the fact that they have something to say about a specific topic, are within the age range, have similar socio-economic characteristics, and are willing to participate in a conversation with the interviewer and each other. The focus group approach was chosen for this study based on the concept of applicability, with participants chosen based on their familiarity with the airline catering business and expertise in supply chain operations. The focus group is one of the common qualitative research tools used for business-related research (Dawson, 2009). This may also be referred as group discussion and group interviews. This research technique has been chosen for this study due to the advantages of obtaining airline catering supply chain process, performance and practices related information from a group rather than individuals by asking about their perceptions and opinion about the situation.

The nature of the airline catering business and the complexity of operational processes required the research investigator to organise brainstorming sessions and team discussions to understand the circumstances thoroughly. It was ideal for delving into the complexities of catering operations, logistics, and other service requirements within the context of supply chain experience, while also encouraging subject matter experts to actively participate in the research process. The experts who took part in the focus group came from various departments within the case study organisation and had varying years of industry experience. Because group dynamics were one of the distinguishing characteristics of focus-group interviews, the type and range of data generated through group interaction were deeper and richer than those obtained from one-on-one interviews in this study. Diverse perspectives on COVID-19 disruption and performance issues affecting catering services, as well as the business justification for low-performing and high-performing supply chain practices implemented in the organisation, were generated through focus-group interviews. The narratives created by operational managers working in warehouse and food assembly areas, although highly distinct, supplemented the breadth of challenges addressed by SMEs from functional departments.

The focus group method aided the researcher in fast gathering a large amount of data regarding the supply chain and understanding the background of the airline catering business. It was difficult to recruit participants for focus-group interviews. To get an idea for forming a focus group, the researcher spoke with a member of the senior leadership team in the case study organisation to understand the skillset, knowledge, and experience of supply chain professionals in advance. Some of the participants worked various shifts. The researcher attempted to avoid the potential issue of the number of non-attendees for focus groups by selecting a date and time that is convenient for all participants and causes minimal disruption to operations. To guarantee full participation, the researcher obtained an agreed-upon date and time from the participants far ahead of the focus group sessions and reminded them a few days before they began. The number of participants in the focus groups varied depending on the project covered in this research. For example, the focus group for the practice effectiveness study had five participants, whereas the focus group for performance metrics development research had ten supply chain practitioners. The number of participants was carefully chosen by the researcher to ensure that the group was manageable but large enough to get a range of viewpoints and small enough not to become chaotic or fractured. Because this is a single case study and the SMEs in the focus group were from the same organisation, all participants felt comfortable with one another and engaged in discussion. The researcher played the role of the group facilitator during the focus group sessions. During the focus group, the researcher took notes and also observed nonverbal interactions, specified the impact of the group dynamic, documented exchanges of opinions about COVID-19 impact and the overall subject of conversation around performance measures, and noted which statement is made by which specific participant. Each focus group session lasted 1.5 to 2 hours, depending on the complexity of the topic discussed, the number of questions asked, and the number of participants. Researcher informed the participants ahead of time about their time commitment. The process modelling focus group session took longer than the focus group sessions used for supply chain performance and practice investigation. SMEs shared their perspectives on process flows and became more involved in streamlining processes and validating business process models during the focus group session.

4.7 Data Collection

In this research, the case study approach was combined with qualitative and quantitative methods. These strategies led to the development of multi research methods covering primary and secondary data collection. This combination of techniques was employed to enable method and data triangulation, strengthening the research findings. The main objective of the data collection phase was to acquire details on the business processes, the choice of performance metrics and considerations, as well as the supply chain practices used in the airline catering supply chain. The information gathered by researchers specifically for the purpose of the research study is known as primary data. In this study, the primary data collection approach was used to gather both qualitative and quantitative data. The primary data for this research study were gathered through observation, interviews, and questionnaires. Electronically saved material that has already been published serves as the secondary data source. Secondary data was gathered by finding information from the various sources of documents that were available at the case study organisation. Some example documents are stated below.

- Standard operating procedures (SOP) documents – A document that describes all processes and activities necessary to deliver catering service to airline customers.
- Catering Procedure Manual (CPM) - A document that includes a summary of catering procedures and policies relevant to caterers.
- Aircraft Catering Manual (ACM) – A document that describes the onboard logistics plans, including galley diagram, stowage summary and packing plans.
- Aircraft Catering Instruction (ACI) - A document to instruct caterers about the changes in the current catering service.

Throughout the study period, all participants were employed in the airline catering industry at various service centre locations in the UK. All participants worked for the same airline catering organisation. The participants had a range of expertise in the subject of logistics and supply chain in the airline catering business, spanning from 5 to more than 20 years. Throughout their previous experience in the airline catering business, the participants handled positions such as supply chain planning, inventory management, procurement management, and warehouse management, among others.

4.7.1 Observation

Observation data collection method is a qualitative research method of gathering and analysing research data by observing the subjects or functions within a specific research environment. This research method is popular in supply chain and logistics research (Sachan and Datta, 2005). Information for this study was gathered by observing the business activities carried out on the shop floor by the case study organisation. Researcher has obtained permission to enter the working environment directly and collect data through observation. Although it provides a decent amount of flexibility for recording data and producing descriptive notes of what process steps are involved in each function, one of the difficulties the researcher encountered with this method was the lengthier time requirement. Since this airline catering operation is 24/7, various critical operations processes are being carried out at different time frames in different shifts. Therefore, researcher had to make several visits to the shop floor at various times of day to capture the operations processes. Researcher also used the observation research method as a verification technique for confirming the information provided in the group discussions. The initial reflection of the researcher was recorded during or immediately following data collection in the form of memos and field notes. Field notes are the documented observations made while conducting fieldwork. Field notes should be taken as soon as possible to provide a record of the research over time (Birks *et al.*, 2008). Researcher used these tools to gather quick observations, ideas, and thoughts while on the shop floor, airside operations of airline catering logistics service. Researcher drafted notes as soon as he observed new activity to maintain the flow of the catering operations process.The date, location, and any observations that were not expressly documented in the data collection are all included in the memos and field notes. These ranged from a few lines to a lengthy paragraph and included illustrations. As opposed to field notes, memos serve as a record of the researcher's thought and reasoning processes after they have been made (Phillippi and Lauderdale, 2018). Field notes may serve as the foundation for memoranda, and memos may eventually represent the researcher's thinking process in linking and understanding the information captured in the field notes (Jain, 2021).

4.7.2 Interviews

Interviewing is a popular and efficient method of gathering data. Researcher used semi-structured interviews to converse with the experts about the catering service operations and related material due to the qualitative nature and philosophical basis of the projects in this research. It is the most appropriate research tool that seems adequate to achieve some of the research objectives. Compared to fully structured interviews, semi-structured interviews offer more flexibility. The majority of the questions were open-ended which allowed experts to answer the questions non-restrictively and encouraged them to reveal business-specific information. This enabled flexible and unrestricted viewpoint exchange between the researcher and supply chain experts who took part in the study. Free flow of expression is crucial for a comprehensive description because it can reveal an understanding of the phenomenon being analysed.

In the literature, interviews have been indicated as one of the appropriate data collection strategies for starting new research initiatives (Adams *et al.,* 2007). Therefore, this data collection method was chosen for the proposed investigatory research. Researcher wanted to seek out detailed information on airline catering supply chain characteristics. Interviews were very beneficial for learning about supply chain practitioners' experiences in airline catering service. Face-to-face interviews were conducted in this study. This provided the opportunity to explain the purpose of the research in person.

Seven supply chain practitioners were initially requested to participate in the study, however, only five (71.4% response rate) agreed to be interviewed. The professionals who volunteered to participate in the study included a mix of senior, middle and lower-level supply chain managers, which decreased bias in responses. Before the interview, the questionnaires were e-mailed to all participating supply chain professionals, allowing them to prepare responses ahead of time. This practice reduced the amount of time needed for interviews. The respondent found it easy to follow the questions during the interview. All of the interviews lasted between one and two hours, and there was no sign of interviewer or respondent fatigue. Interviewees appeared to enjoy the interview, because the study centres on airline catering service and business processes related to the logistics operations in the airline catering organisation.

The study questions had a broad framework, concentrating on the how and why of airline catering supply chain execution, and hence did not need the assistance of an expert for developing interview questions. Interviews were useful as researcher has little knowledge about airline catering operations. Researcher was able to collect good background data about the airline catering service and operational functions of the case study organisation. Researcher prepared a list of key themes, characteristics, and questions to address. When conducting the interviews, researcher used a basic checklist to ensure that all relevant areas were covered (i.e. catering service, operations, and systems). Depending on the direction of the interviews, the researcher sometimes changed the order of the questions during the interview. Researcher asked additional questions as follow-up questions based on the subject matter experts' further experience and opinions on the airline catering service and supply chain operations.

4.7.3 Questionaries

Questionnaires method is a research tool that consists of a series of questions designed to collect data from respondents. Questionnaires are similar to written interviews in that they collect information. They can be done in person, over the phone, on the computer, or by mail. A questionnaire typically contains both open-ended and closed-ended questions in order to gather data. Questionnaires have long been used as a technique for data collecting. The selected sample of respondents is issued a standardised questionnaire with closed or open-ended questions. questionnaires are useful in descriptive, exploratory, and investigatory research.

This data collection method was helpful since it enabled the collection of both quantitative and qualitative data. The organisation's preferences for performance metrics, SME's opinions about performance considerations changes, and measuring the performance and importance levels of supply chain practices in the airline catering organisation were all quickly and effectively assessed through the use of questionnaires. The questionnaire for this case study research was a combination of open-ended and closed-ended questions. Supply chain practitioners in the airline catering organisation were expected to offer their own opinions and experiences in the case of open-ended questions. An open text area was provided for this purpose on the distributed questionnaire. In the case of closed-ended questions, the researcher provided a list of alternative responses.

Academics and practitioners in the airline catering supply chain examined the initial questionnaires for substance, clarity, and ease of comprehension. The review was carried out by three academics, two of whom were the research supervisors and one from another university. In addition, the questionnaires were reviewed by two senior supply chain professionals from airline catering organisations. Following review feedback from academics and supply chain professionals, the questionnaires were revised.

Google Forms online service was used to build the questionnaires. It is a free online service with an easy-to-use graphic user interface. The link to the online questionnaire form was emailed to research participants. A total of 12 people were selected for the questionnaires. The link was given to the 12 questionnaire participants targets, and 10 replies were received. This equates to an 83% response rate, although it should be noted that the limited sample size was due to theoretical sampling and the investigatory nature of the study. While the majority of the participants completed the questionnaire form on their own, four people phoned the researcher to discuss the purpose of the study and each item on the questionnaire for further clarification.

During the research on performance metrics development, researcher had to organise selected performance metrics into distinct priority categories. As possible answers to prioritisation queries, a list of four MoSCoW priority ratings (Must have, Should have, Could have, Won't have) was supplied. To comprehend the performance considerations changes during COVID-19, closed-ended questions with possible responses of the level of change (Very high increase, High increase, Little increase, No change, Little decrease, High decrease, Very high decrease) were used. Experts were given closed-ended questions to rate the performance and importance level of each practice effectiveness factor for the assessment of supply chain practice effectiveness in the case study airline catering organisation. Practice effectiveness factors are composed of the following constructs: (1) Performance attributes; (2) Practice categories; and (3) Supply chain practices. Participants were asked to select linguistics values from a response set for importance weights (Very low, Low, Fairly low, Medium, Fairly high, High, Very high) and performance ratings (Worst, Very poor, Poor, Fair, Good, Very good, Excellent).

4.8 Data Analysis

This research study was initiated with a detailed investigation which was undertaken to determine the processes performed by the airline catering supply chain organisation and the requirements for the business process integration and new process design for airline catering logistics operations. This involved discussing with the SMEs of the various supply chain functions, brainstorming sessions, examining all the logistics processes and practices involved on the shop floor, and understanding their performance considerations. The analysis provides the foundation for business process modelling. The analysis phase of this research examines the collected data to propose an airline catering logistics process design, develop performance metrics, and evaluate supply chain practice effectiveness. During the analysis phase of the process modelling project, the researcher investigates the existing supply chain processes and begins to form impressions of the new process map for the airline catering logistics execution function.

4.8.1 Qualitative Data Analysis

Business Process Management is a discipline that provides concepts and techniques for organisations to optimise, configure and execute their business processes in an effective and efficient way. Process analysis is one of the critical steps in business process management. It analyses the current state of the processes using different techniques to gain insights into the areas of improvement and to identify possible options for optimising and redesigning the processes.

In this thesis, the process modelling project aims to look for potential opportunities for business process integration of logistics operations within the airline catering supply chain. The qualitative method is used for analysis and modelling in this project. SIPOC analysis was applied when analysing the current process, and the BPMN technique was adopted for detailed process modelling of airline catering logistics processes.

SIPOC is commonly used for process design and continuous improvement initiatives such as six sigma to identify the key process elements and define the project scope. In this project, SIPOC analysis is used during the identification and documentation prior to the detailed process mapping stage. The SIPOC diagram in Figure 4.3 explains this in detail.

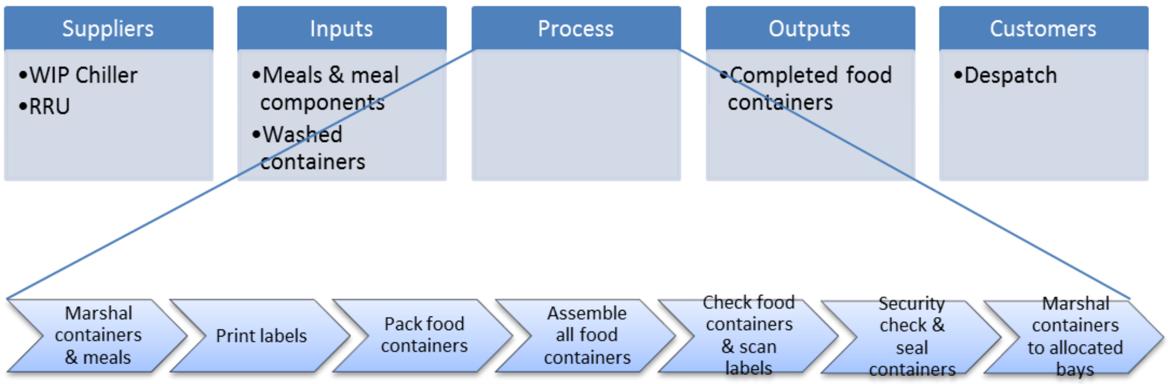


Figure 4.3 Food Assembly Process

SIPOC analysis was used in the focus group to allow the participants to agree on the core processes involved in the airline catering logistics operations. It helped the researcher and focus group participants see the relationships between the process inputs and outputs and realise the potential gaps and integration points between the core processes.

In order to support business process integration for the airline catering supply chain, the research must practically correctly model the processes across the catering logistics operations. The business process analysis using BPMN demonstrates the interaction between the business processes and the impact of the transaction at each process step in the internal supply chain. In the part of this research, the researcher examined how the internal supply chain can be made effective by integrating all the business processes in the logistics operation. In this research study, the researcher looked at the process mapping, modelling, and business process integration needed to improve the airline catering operation.

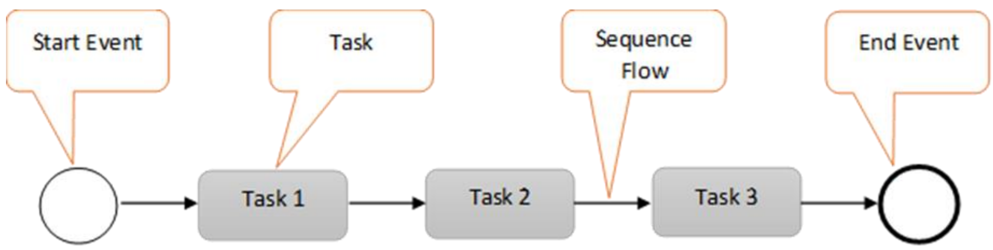


Figure 4.4 Simple process model

A simple process model is illustrated using BPMN elements in Figure 4.4. Some of the core elements are start event, tasks, sequence flow, gateways and end event. They are listed in Table 4.2. Start event initiates the process scenario. Tasks are the activities which represent the individual steps of a process. Sequence flows are used to link every element within a process scenario, and gateways are used to control the flow of the process. End event denotes the end of the process (Khabbazi *et al.*, 2013).

Table 4.2 Essential BPMN elements

Start Events	Initiate a process case
Tasks	Activities that represent individual steps within a process
Sequence Flows	Connect the elements of a process (Tasks, events and gateways)
Gateways	Control the flow of the process
End Events	Complete the process case

The qualitative analysis approach used in process analysis and design helped the researcher to understand and categorise business processes and, recognise any weakness of current design and improvement opportunities. It was easier to understand and maintain the relationship between core processes of airline catering logistics through qualitative process analysis.

4.8.2 Quantitative Data Analysis

The practice effectiveness project adopted a quantitative data analysis approach primarily using the fuzzy logic method. Fuzzy logic is widely used for scientific evaluations in various disciplines. It can be viewed as a tool to translate ambiguous statements from natural language into mathematical and logical statements (Rostamzadeh et al., 2018). Fuzzy logic plays an important role in a variety of fields, including operations management and supply chain, e.g. (Islam et al., 2018). Fuzzy logic is applied in real-world applications with uncertain situations (Yasin Al et al., 2016). The fuzzy logic approach used in this research deals with the lack of clarity related to the evaluation measurement of supply chain practice effectiveness.

Fuzzy logic is a multi-valued analysis method that was introduced by Zadeh (Azadegan *et al.*, 2011), designed to deal with uncertainties and subjectivities in a decision model (Ganga and Carpinetti, 2011). Uncertainties and imprecision are inherent factors that affect the supply chain's evaluations and decision-making. Applications and tools based on fuzzy logic allow uncertainty and imperfect information to be included in evaluation and decision-making models, making them suitable for supply chain evaluations. Fuzzy logic approach resembles human reasoning and processes a degree of truth rather than the traditional true or false Boolean values. Fuzzy logic uses linguistic variables whose values are expressed by natural language words or sentence in non-numerical form. The concept of linguistic variables is useful for dealing with situations and a complex status quo which are difficult to define well quantitatively.

Linguistic expressions provide more information than numeric ratings, as in many situations, it is not practical to put the score of a hazy indicator by using a numerical evaluation structure. Hence, linguistic terms were used in the performance metrics development research to assign the importance weights to the performance attributes, practice categories and supply chain practices. Linguistic terms were also used to assign performance ratings to the supply chain practices. Linguistic expressions and relevant membership functions for the importance weights and performance measures used in Chapter 7 were adopted from the literature.

Fuzzy arithmetic operations play a vital role in science and engineering applications. When performing arithmetic operations with fuzzy numbers, the calculations' outcome heavily depends on the shape of the membership functions of those numbers (Yasin Al *et al.*, 2016). Triangular fuzzy number (TFN) is the simplest form of a fuzzy number (Voskoglou, 2016). Hence, researchers mainly use TFNs in several applications (Ban and Coroianu, 2015), and it is used in Chapter 7. A TFN is defined as (a, b, c), where the parameters a, b, and c of the TFN represent the small value, middle value, and large value, respectively. The TFN is characterised as shown in Figure 4.5.

(i) a and b is increasing function
(ii) b and c is decreasing function
(iii) $a \leq b \leq c$.

$$\mu_A(x) = \begin{cases} 0, & \text{for } x < a \\ \dfrac{x-a}{b-a}, & \text{for } a \leq x \leq b \\ \dfrac{c-x}{c-b}, & \text{for } b \leq x \leq c \\ 0, & \text{for } x > c \end{cases}$$

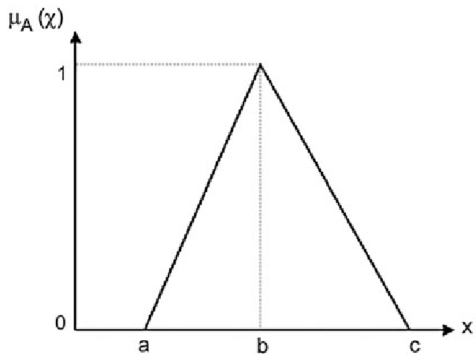


Figure 4.5 Triangular membership function

A positive triangular fuzzy number A is represented as $A = (a_1, a_2, a_3)$, where all $a_i > 0$ for all $i = 1, 2, 3$. A negative triangular fuzzy number A is represented as $A = (a_1, a_2, a_3)$, where all $a_i < 0$ for all $i = 1, 2, 3$. A partial negative triangular fuzzy number A is represented as $A = (a_1, a_2, a_3)$, where at least one $a_i < 0$ for all $i = 1, 2, 3$. The triangular fuzzy number set is easy for the decision-makers to use (Shen *et al.*, 2013) and easy to perform mathematical calculations involving addition, subtraction, multiplication and division on fuzzy numbers.

Let $A = (a, b, c)$ and $B = (a_1, b_1, c_1)$ be two triangular fuzzy numbers. The basic arithmetic operations of TFNs over A and B are expressed in Equations (4.1) - (4.4) (Rostamzadeh *et al.*, 2015).

Addition, $$\boldsymbol{A \oplus B = (a, b, c) \oplus (a_1, b_1, c_1) = \{(a + a_1), (b + b_1), (c + c_1)\}} \quad \textbf{(4.1)}$$

Subtraction, $$\boldsymbol{A \ominus B = (a, b, c) \ominus (a_1, b_1, c_1) = \{(a - a_1), (b - b_1), (c - c_1)\}} \quad \textbf{(4.2)}$$

Multiplication, $$\boldsymbol{A \otimes B = (a, b, c) \otimes (a_1, b_1, c_1) = \{(aa_1), (bb_1), (cc_1)\}} \quad \textbf{(4.3)}$$

Division, $$\boldsymbol{A \oslash B = (a, b, c) \oslash (a_1, b_1, c_1) = \left\{\left(\frac{a}{a_1}\right), \left(\frac{b}{b_1}\right), \left(\frac{c}{c_1}\right)\right\}} \quad \textbf{(4.4)}$$

4.9 Reliability and Validity

The validity of the research has been evaluated in terms of its value, the models and tools that have been developed, and the research methodologies, such as data collection and analysis. The validity of business process models has been established by the researcher using skilled industry experts. Two stage design review process was organised to verify both the quality and the coherence of process models and confirm that BPMN elements are illustrated accurately to represent the process logic. Furthermore, Researcher validated the contents through focus group participants, by asking them to double-check how the observation field notes are recorded and transcripts are produced, along with the ideas and concepts, and how well they match the problem being investigated. The contributions of senior supply chain managers of the case study organisation in the development of the performance metrics questionnaire assured content validity. Researcher applied a comparison check while capturing many viewpoints in order to examine similarities and differences.

The researcher went through different stages to ensure the reliability of the research. The first step involved compiling the data into a table to provide a summary of the data collection procedure and an ongoing assessment of the outcomes. By using a table to keep track of data, the researcher was able to quickly evaluate the findings in light of each respondent's record and understand the progress of the research. The table was also useful in the effective calculation of practice effectiveness measures and in creating a conclusion summary of the research considerations.

For practice effectiveness research, the reliability was also assessed through tool testing. To test for the Excel based effectiveness evaluation tool, researcher has performed all four staged calculations manually to confirm the results. Additionally, the tool was also tested using different inputs, wherein other research works in the different fields using triangular fuzzy numbers calculation were used to evaluate the tool. The different parameter values from other research were applied to the Excel tool and confirmed the results presented in the literature review to support the Excel tool reliability and the calculation results of the practice effectiveness measurement process.

The reliability and validity of the research were also enhanced using the data triangulation method. This essentially means that the study was undertaken from several or various angles. For example, researcher discovered information by searching the various document sources available in the case study organisation such as Standard Operating Procedures (SOP) documents, Catering Procedure Manual (CPM), and Aircraft Catering Manual (ACM). Additionally, he collected data by observing the operational activities on the shop floor and discussing with experts in focus group meetings. Basically, these different data collection methods enabled the researcher to cross-check the findings and examine the data from different angles. Furthermore, the reliability measures relating to the triangulation of data gave a thorough comprehension of the research objectives, adding another degree of reliable authentication to the study.

4.10 Chapter Summary

This chapter defines the research process, establishes the philosophical approaches used in this study and justifies the research methods adopted in this research. Data and information are collected through conducting primary and secondary research methods as stated in the previous section. Various procedures and ideas from subject matter experts in the airline catering business are used for gathering important data and gaining industry knowledge. The analysed data and process knowledge aim to discover the business requirements. This thesis contains inclusive information regarding catering processes, performance measures, current supply chain practices of the airline catering industry, operational complexities, and opportunities. Key factors, business challenges, and improvement opportunities are outlined in the research study to help the researcher develop methodologies for SCOR-based industry solutions.

The research methodology used in this study has the following benefits:

- Industry-driven approach
- Focus on specific process knowledge
- Data collected from interviews with subject matter experts
- Key logistics service analysis
- Gathering of information from authentic primary and secondary sources

5 Process Modelling

5.1 Introduction

Logistics execution is one of the essential components of airline catering supply chain management. Increasingly, airline catering companies are required to manage complex logistics processes due to the competitive nature of the business, advances in supporting technologies, and the need for sustainability. A key challenge is ensuring that the business processes of airline catering supply chains support the service objectives of the business and that the processes are appropriately integrated. Inevitably, a concern of the challenge is the sustainable design of logistics execution processes. There are various process steps carried out by different functional areas, such as material management, order fulfilment, production, and warehouse management. Effective communication and collaboration among these functional departments, including doing things right, are necessary for sustainable logistics execution.

Airline catering companies increasingly engage in the demand-driven supply chain, and it uses the demand-pull approach that requires more real-time collaboration. Demand-driven supply chain design enables companies to improve responsiveness and agility, the two performance attributes defined in the SCOR model and provides better supply chain visibility. Companies can adapt to the dynamic changes in the airline environment flexibly to respond to external influences and increase visibility through transparency across their business functions.   This project establishes the business process modelling framework which can support business process integrations with the information systems and enhances agility and responsiveness capabilities as needed in such a dynamic airline catering supply chain.

Organisations are increasingly relying on information systems to support their process improvement initiatives. The introduction of IT created new opportunities for enterprises as many of them are interested in solutions that focus on the business processes and manage them in a better way to increase their operational efficiencies (Lee *et al.*, 2005). Airline business and its catering operation are extremely dynamic and fast-paced environments. Bringing supply chain systems and technology to the airline catering workplace is inevitable. This project addresses the need for developing the approach that can be used by airline catering organisations that are motivated to develop enterprise software applications related to airline catering systems. This research project aims to develop an understanding of internal supply chain functions for a particular organisation in the airline catering industry and develop a business process modelling framework to design an integrated solution for its logistics execution based on the SCOR framework. It is intended to link the operational language and discipline of airline catering with the modelling language and principles of information systems engineering. This study facilitates the development of concepts and methods for representing business processes, models and elements that correctly represent the views and needs of airline catering professionals.

BPI becomes a potential solution in resolving the integration problems for the airline catering supply chain and adapting sustainably in logistics service. To integrate the logistics business processes and to achieve a sustainable airline catering supply chain, this research proposes a process design for logistics execution. The objective of this project is to explore the logistics processes of airline catering operations and establish business process models for designing integrated business processes and enabling information systems in the airline catering supply chain. Need factors for business process integration of logistics operations were initially collected through the literature review and interviews with subject matter experts in the airline catering industry in the UK.

The motivating force of an integrated logistics execution system is the ability of airline catering organisations to transform their catering services through the sustainable integrations of business processes. Additionally, airline catering organisations are developing a value chain approach, including the other stakeholders in the airline carting supply chain, such as airline customers and food suppliers. The BPI will help airline catering companies better perform primary functions within the value chain.

The SCOR model can be used to develop a framework for mapping business processes and measuring the performance of the airline catering supply chain. But, the SCOR model needs to be adapted according to the organisation's supply chain requirements. This chapter describes how the business process reference model was created using the SCOR framework. Primarily, the reasons for the proposed changes and underlying principles of the airline catering SCOR model are stated. Finally, three core business processes in airline catering logistics are analysed, and the details related to the application of the design framework are discussed.

5.2 Business Process Integration

To incorporate the agile and responsive supply chain performance aspects in airline logistics operations, this section introduces the concept of BPI and the importance of information flow for effective logistics operations. Business Process Integration (BPI) is a methodology that helps organisations to work together with their trading partners, suppliers and customers through the integration of processes to achieve better results. Organisations are trying to redesign the way activities are done and reengineer the business processes to produce environmentally friendly products and services and support their sustainability goals. Business Process Reengineering streamlines functional processes by eliminating waste, simplifying and integrating the processes. Business process integration is one of the BRP principles mainly used in functional applications to enable process improvement (Samaranayake, 2009).

The main reason many organisations choose to implement business process integration is to enhance efficiency. Integrating an organisation's business processes using information systems is often convenient and improves productivity by removing significant delays in information transmission across functional departments. Enterprise Resource Planning (ERP) system is one of the key enablers for business processing integrations and the main driver of supply chain efficiencies. ERP system is used for managing business processes. It enables the integration of organisational resources, business functions, customers and suppliers of the organisation. This integrated system facilitates the integration of business applications used by individual departments. It manages a vast amount of data in a single database. It offers centralised data management but decentralised access control. It provides a view of the entire business operations, enabling functional managers within each department to have access to information regarding the internal supply chain. ERP systems can integrate a high volume of data and business processes across many departments and business units in different geographical locations.

Based on the deployment, these systems can be classified as on-premise deployment and cloud-based deployment. Some of the key functions of the ERP system consist of logistics execution, human resource management, customer relationship management and finance. Materials management, vendor performance management, production planning, and order fulfilment are all logistics functional benefits of ERP systems. Manufacturing, healthcare, telecom, utilities, retail, consumer products, aerospace, and defence are among the key industries served by ERP systems. ERP market segment is classified into small, medium, and large enterprises as per the type of end-users and the size of their business.

ERP system and its business process integration capabilities play an undeniably vital role in sustainability, agility, visibility, responsiveness, and cost reduction. These aspects are often discussed in the supply chain discipline, particularly in relation to improvements in the internal supply chain. But, only a few organisations are leveraging ERP systems effectively to manage the internal supply chain. Many companies utilise a small percentage of their ERP system's functions. Most business users do not even realise a substantial percentage of what their system could be capable of.

Specific processes for airline catering, like planning for the aircraft galley and stowage, as well as onboard menu planning based on sophisticated airline catering rules, call for a large amount of customisation in traditional ERP systems. Besides, the airline business is a highly dynamic business environment. Airline catering requirements constantly keep changing due to the need for the most cost-effective catering service, demand from airlines for the new menu or meal specifications or regulations from government and aviation authorities. Airline catering organisations' competitive advantage may be weakened by the adoption of proprietary enterprise software, such as standard ERP systems, which may impose a more rigid structure on them. Moreover, airline catering companies have more to risk by standardising core business functions, and by adhering to standard proprietary ERP system that limits their flexibility to adapt to ever changing internal and external factors. The ERP system needs to adapt to these business changes. The ERP software must therefore be adaptable enough for the airline catering organisation to change it and add new features as needed. This is not feasible with a proprietary standard ERP system. The best course of action is to develop ERP applications that can be tailored to their unique airline catering business requirements, increasing their competitiveness.

Despite the comprehensive functionalities and system capabilities of ERP systems, successful business process integration is not always guaranteed. Suitable functional specifications and an understanding of design requirements are critical to configuring the system to the unique requirements of a business. The research work reported in this chapter analyses the specific needs and design requirements of airline catering logistics services to design airline catering logistics processes. This will assist airline catering organisations with successful business process integration using an ERP system or similarly capable information systems.

5.2.1 Business drivers for business process integration

There are several factors that influence the business process integration in the airline catering business.

1. Understanding – Increased shared understanding among functional departments and get the entire organisation to align with business changes and sustainable service strategy.
2. Visibility – See how the catering service is impacted by behind-the-scenes logistics operations.
3. Agility – Respond quickly to the service changes in airline catering demand or customer expectations.
4. Cost - Recognise and remove costs that do not contribute added value to airlines by optimising processes to improve efficiency.
5. Excellence – Deliver outstanding service standards for the airline customer and provide an excellent customer experience that keeps them continuing the service contact for a longer period.
6. Empowerment – Empower organisations to think of continuous improvement and innovative ideas.

Understanding Business Change

The changes in the airline business environment are inevitable. However, the pace of changes is accelerating, which has a great impact on the catering business. The way onboarding service was offered a few years ago is not satisfactory if airlines want to stay competitive. The change includes how the airline interacts with the catering service providers, what improved service they are offering to passengers, what changes airlines are making to reduce the catering cost, how the meals are prepared, and how it is packed and transported to the aircraft (Szymanski, 1995). The changes in the airline catering business are essential and unavoidable. Major changes are normally implemented during the seasonal schedule and menu change (Jones, 2012b). There are significant changes in flight schedules and meal offerings when the winter and summer period starts. Other frequent ad-hoc changes are communicated with the service providers formally via a document called 'ACI-airline catering instruction'.

Airline customer places catering order over the internet. Then, there can be some changes in the existing order. It includes passenger number fluctuation, special catering requirements, aircraft changes, and schedule changes requiring different meal offerings. Accommodating these changes and fulfilling the customer order in a timely manner is a challenging task for catering service providers. This requires broad integration of catering information across all logistics functional areas (Kumar and Sharma, 2021).

Business Visibility

Business process integration will improve the visibility of airline order information across functional areas by linking the related logistics processes together (Romano, 2003). The competitive advantage of airline catering logistics requires enabling the end-to-end processes across the service value chain, from passenger forecasts to airline order fulfilment, as fast and effectively as possible. An organisation should be able to view and manage logistics processes in real time. To achieve this, it requires a logistics execution system to integrate, monitor and manage end-to-end business processes across the functional areas and the whole value chain (Abreu and Alcântara, 2015).

Business Agility

The ultimate aim of a catering service provider is airline business agility – the ability to accept service changes quickly. Real-time logistics has become a catering strategy because it enables catering service providers to respond to the rapidly changing airline business environment (Rahardjo, 2021). Real-time response to ever-changing catering instructions requires a BPI framework that enables the implementation of integrated logistics execution. The agile nature of the airline catering business requires real-time interaction between business processes. Catering service providers need to monitor and manage the business processes in real-time to continuously improve the catering logistics service and optimise the functional processes (Yusriza *et al.*, 2022). Without business process integration, catering service providers may continue to be restricted by the inability to manage the flow of information and streamline logistics processes across the business unit.

Reducing Cost

Lack of interaction between multiple systems requires additional manual intervention such as re-entering the same business information, increasing the risk of potential errors. The cost of rectifying such errors may not be small. The BPI approach will help reduce admin time and cost by avoiding any manual entry and simply reducing process errors (Hallikas *et al.*, 2019). Labour costs can be reduced by reducing the headcounts required to maintain the system (Hallikas *et al.*, 2019). Through business process integration, catering organisations can standardise their service offering with a smaller no of employees. They can eliminate manual business transactions and improve process efficiency and overall service quality. This will help them reduce the cost per meal and per airline order.

Excellence through Customer Satisfaction

Customer satisfaction is gaining more importance in this airline catering business (Ernits *et al.*, 2022). Business process integration can increase customer satisfaction by keeping catering information simply available and responding to customers' queries and complaints promptly and professionally. Catering service providers will be able to view future orders and materials demand, track airline orders, and change information such as passenger number updates or aircraft type changes. Airlines will be happier since their catering needs will be met quickly, and customer interactions will improve at every stage of the catering service.

Empowering Business Process Improvement

Business process integration will improve the IT applications' performance and logistics processes by implementing real-time workflows and reducing the latency times between the functional processes (Kayikci, 2018). Enabling the flow of information as it exchanges between the business processes greatly reduces the delay time in logistics execution and allows real-time decision making (Kisielnicki and Markowski, 2021). Through business process integration, catering organisations can perform their service better, faster and cheaper. They can, for example, minimise inventory costs by improving insight into catering logistics, better planning warehouse capacity, and optimising production and assembly processes.

5.2.2 BPI design for Airline Catering

Business process integration of airline catering logistics service refers to the business process model defined through airline catering logistics workflow requirements, sequence, hierarchy, the logic of logistics execution, and information flow between core processes within the airline catering organisation. It specifies the way to bridge the key processes of airline catering logistics function. A BPI design for the airline catering business is illustrated in Figure 5.1.

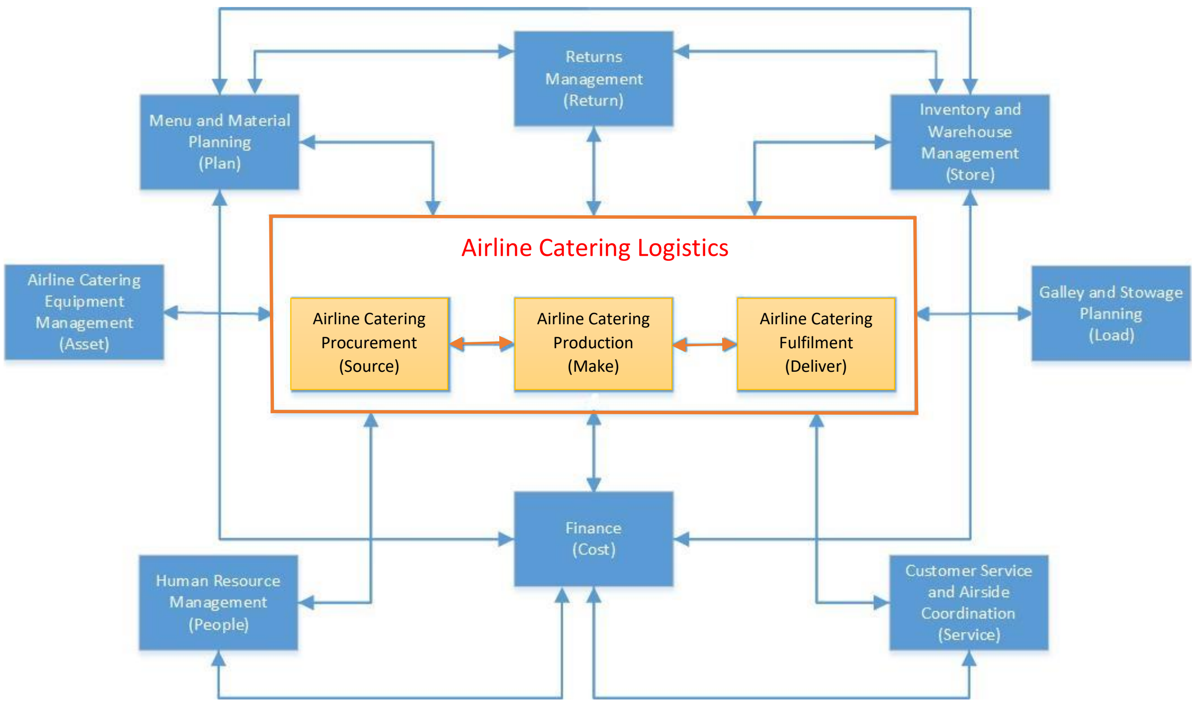


Figure 5.1 Business Process Integration in Airline Catering

Airline catering organisations attempt to synchronise their internal logistics processes and extend the connectivity to external processes like airline and food, and non-food supplier related processes. A most common approach to achieving the BPI is linking the organisational business process models. BPI of airline catering logistics can be achieved through integrated business process models of airline catering organisations' core logistics processes - airline catering procurement, airline catering production, and airline catering fulfilment.

5.3 Methodology

This study employed the design science research methodology, which focuses on "how" questions, such as how to develop a model or system that solves a specific problem (Van Aken, 2004). In this methodology, the knowledge and understanding of the problem domain and proposed solutions are obtained through the development and application of artefacts (Hevner *et al.*, 2004). This project addresses the question of "how to design process models that support business process integration of airline catering logistics operations". In this approach, first generic business understanding and design knowledge was developed based on the requirements analysis, and then the applicability of designed process models was validated using a case study.

First, the researcher conducted a review of the existing literature on supply chain management from reviewed papers and journal publications to define supply chain processes and identify the essential components of supply chain systems. For this research, the researcher approached supply chains from a systems perspective because it allows the representation of interactions between processes systematically. Basic design requirements for reference process models in airline catering supply chains were specified based on the literature review of the SCOR model. Researcher also interviewed airline catering logistics professionals and supply chain systems experts to discover any industry-specific requirements and functional processes not included in the literature that can be used for the development of general design requirements. This work was carried out by the researcher through observation and field study and also informed by logistics management experts and supply chain professionals in the airline catering organisation.

Initial analysis of airline catering logistics processes suggested a business process management approach for ensuring dynamic supply chain requirements: Designing customised logistics execution through business process integration using a reference model. To appreciate the effect of business process integration on airline catering supply chain and logistics operations to reduce the complexity of this business, the researcher examined various business processes involved in airline catering logistics operations in detail. Because the availability of meals, beverages and equipment supply is crucial to delivering effective airline catering service, this project developed a design framework for process modelling to support business process integration, as illustrated in Figure 5.2 that can be applied in the airline catering supply chain domain, and more specifically to catering logistics operations.

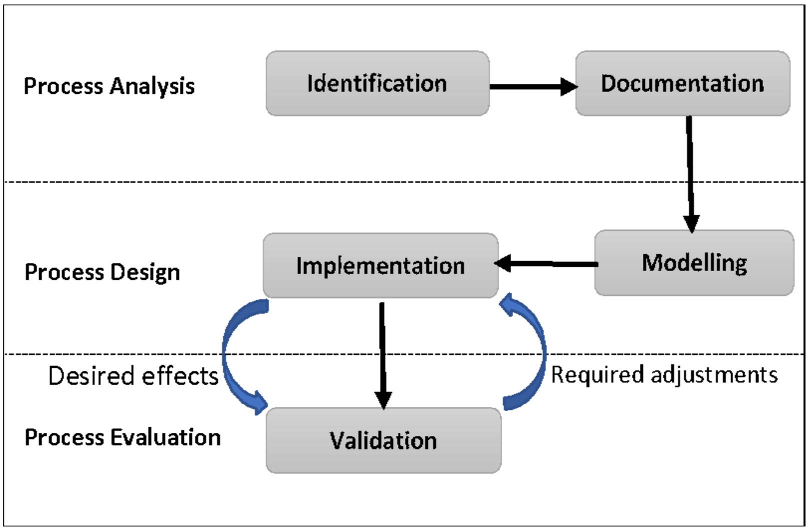


Figure 5.2 Business Process Design Framework to Support Business Process Integration

The proposed design framework covers various phases throughout the implementation of business process integration. It consists of 5 different phases. The business process design phases are: (1) Identifying the business processes, (2) Documenting the business processes, (3) Modelling the processes using graphical language specification, (4) Implementing the business process in enterprise applications and, (5) Validating the outcome of the implemented process.

Identification

As the initial step in adopting business process integration, the processes must be identified. The identification phase's goal is to recognise all business processes and classify them under each process category. It categorises all the business processes and their inter-relationships. Using business process mapping tools is the best approach to accomplish this.

Documentation

Existing processes within the businesses must be documented in order to comprehend and share the processes' specifics. Business process management (BPM) tools can be used to build process flow diagrams and other visual illustrations that explain essential business process details. Documentation is a means of communicating processes to stakeholders. Stakeholders can see, approve, and recommend improvements for listed processes. The documentation must specify how the organisation's business processes operationalise its strategy. One of the primary obstacles is accountability for cross-functional process performance. As the organisation chart typically does not reflect this, the documentation should clarify the process owners or roles accountable for taking corrective and preventive action when process performance falls below the acceptable threshold. Airline catering companies must adhere to several regulations. It is crucial that they document their processes and adhere to the standards of authorities such as the Civil Aviation Authority (CAA) and the Environmental Agency. Reviewing and evaluating documented processes ensures that all real-time operations are captured. It will also help in identifying process inefficiencies and chances for improvement.

Modelling

The next step in the BPI implementation is to create models of the processes to demonstrate the planned improvements and any extra features to be conceptually incorporated within the system. During this step, process models are created with the essential illustrations of proposed changes. This will assist process owners in understanding the potential outcome of the modifications and determining whether any process inefficiencies discovered in a prior stage have been adequately addressed. Some simulations allow the suggested modifications to be hypothetically executed, and the results can be examined and evaluated prior to actual implementation.

Implementation

This is the actual process of making changes, transforming the proposed model into an executable business application of the enterprise systems. This includes system development, appropriate configuration and customisation as per the business needs. After the business process models have been assessed, implementation is the actual process of coordination of business processes among functional departments and with its customers and suppliers by connecting disparate application modules and systems in real time. It increases the operations efficiency of the business and avoids the requirement to duplicate data in the different functional modules.

Validation

This phase is monitoring the effect. Organisations review the processes post-implementation to assess the impact of the BPI and expected improvements to the business processes. Organisations can monitor their processes after the implementation to evaluate whether the business process integration has the desired results or make required adjustments and improvements.

Based on these five phases of BPI implementation, the design framework is discussed in this section as IDMIV (Identification, Documentation, Modelling, Implementation, Validation). This IDMIV framework uses systematic evaluation to monitor and assess the BPI progress before, during and after the implementation. The main scope of this project is designing the process models; hence only the identification, documentation, and modelling stages have been applied to the case study, and actual implementation and validation are not covered in this project. However, experts have assessed the designed process models to confirm their suitability in a design review session.

As per the design framework, the first step of the case study was identifying the current business processes which were not clearly defined and understood. AS-IS business analysis has been conducted to understand the business processes of airline catering logistics operations at a high level without going into more detail. Researcher has participated in and observed the shop-floor operations to capture current business processes in the warehouse, and food assembly operations at company X, and focus group sessions with subject matter experts from the operations and IT team were organised to validate those processes. Business stakeholders who participated were chosen for their expertise in the functional areas. They were shift operations managers, senior operations managers and IT managers. This activity involved modelling business processes in the logistics operations areas of company X. In the second stage, the analysis study documented the current state process analysis to summarise the findings of a review of logistics operations at company X by outlining the current processes, systems, issues, and opportunities that have not been studied for a long time. SIPOC tool was used to document business processes from beginning to end in all warehouse operations and food assembly areas. SIPOC is a high-level diagram which provides a structured way to define the process. Researcher used this visual tool to discuss and identify the processes through brainstorming sessions. Following the identification and documentation stages, the researcher has gained a good overall understanding of an airline catering organisation's internal supply chain management structure. Then he began to analyse the requirements of information flow across its functional departments in the internal supply chain and started detailed modelling using the BPMN method, a global standard for process modelling. Before designing the solution artefact, it is necessary to understand and define the necessary workflow activities under various real business scenarios. This step has begun with an analysis of business processes that have been captured. Then researcher gradually moved into SCOR framework knowledge to develop a reference model suitable for airline business and finally designed the process architecture and business process models based on the hierarchical SCOR reference model for specific airline catering requirements. These designs have been systematically inspected using a focus group which consists of a panel of experts from the case study company.

5.4 SCOR-based Reference Model

As previously stated in this thesis, it was decided that the SCOR model is a suitable framework for mapping airline catering supply chain processes in this project. However, as mentioned earlier, the SCOR model had to be adapted to meet the needs of the airline catering business.

By SCOR definition, “A process is a unique activity performed to meet predefined outcomes”. The SCOR framework offers a number of predefined process definitions for logical process maps. The processes in the framework have been recognised as unique processes that a supply chain needs to function to support the primary goal of fulfilling customer orders. The SCOR framework can be used as the reference model to conceptually map the workflows and activities performed in a supply chain. It provides the structure to define the process architecture for different businesses and industries to align their business functions and objectives.

Researcher designed airline catering logistics processes using the SCOR reference model of hierarchically organised process flows. Before demonstrating the airline catering process landscape and relating each workflow activity in the business process model, it’s important to describe the underlying hierarchical structure of the SCOR process model, as shown in Figure 5.3.

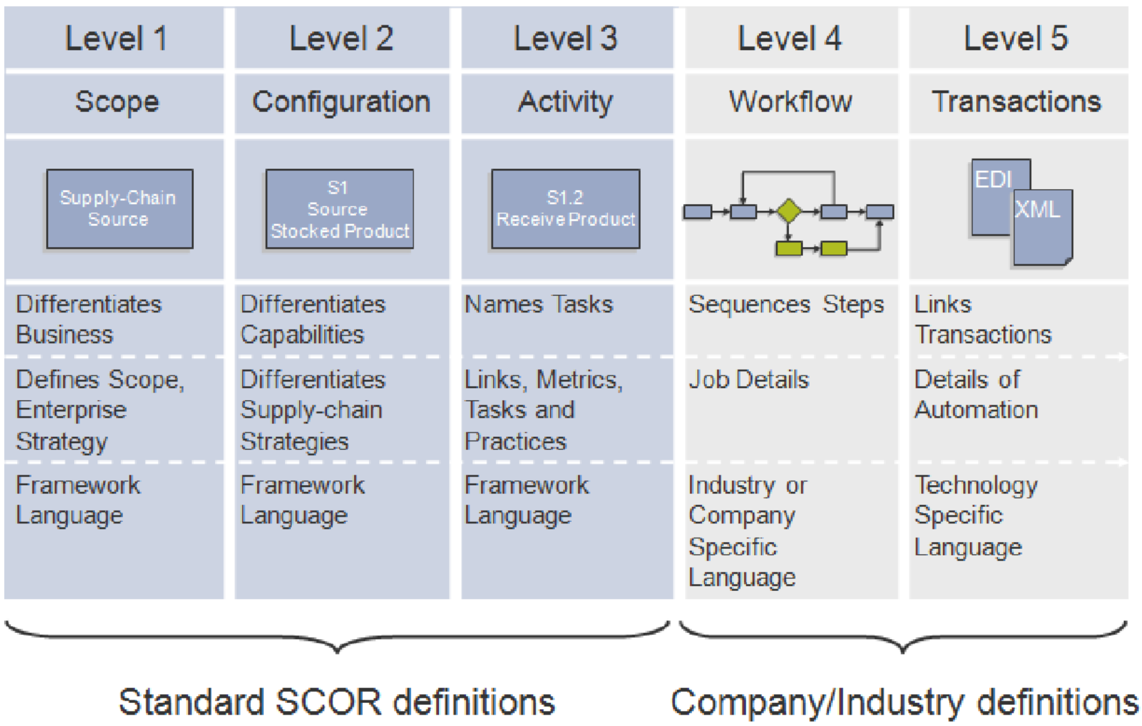


Figure 5.3 SCOR Process Hierarchy (Gemesi, 2010)

In hierarchical order, the first three levels of the SCOR reference model define the standard supply chain processes. This reference model can be used in a variety of sectors and businesses, including the airline catering industry, due to the hierarchical nature of the processes. The model can be further extended according to the industry definitions. Level 4 is the workflow level which is unique to each industry and organisation. In provision for the tailoring workflow of airline catering logistics, this section provides an overview of the framework in multiple levels.

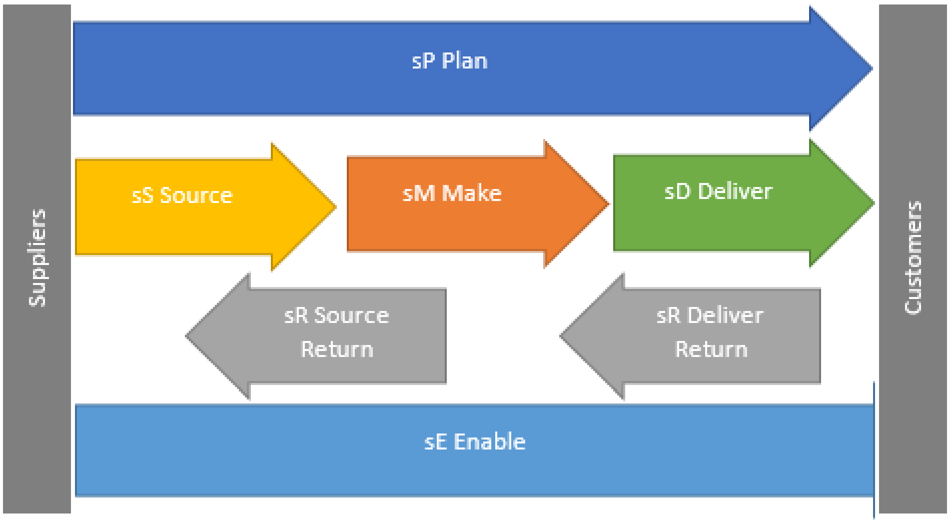


Figure 5.4 Level 1 major processes in SCOR model

The reference model focuses on the top three levels which are industry neutral and helps supply chain practitioners to analyse their supply chain. The model's first level (level 1) is composed of six key processes and is considered a strategic level. This is where the core processes of the organisation's supply chain take place. Figure 5.4 shows the schematic flow of the supply chain on level 1, which is modelled with the major processes Plan, Source, Make, Deliver, Return, and Enable.

Plan: Determine resources, requirements of the supply chain

Source: Procurement of products and services to meet the demand

Make: Production of goods or services as per the demand

Deliver: Fulfilment of customer demand, distribute finished goods

Return: Receipt of returned goods from customers/return products to the supplier

Enable: Management of the supply chain

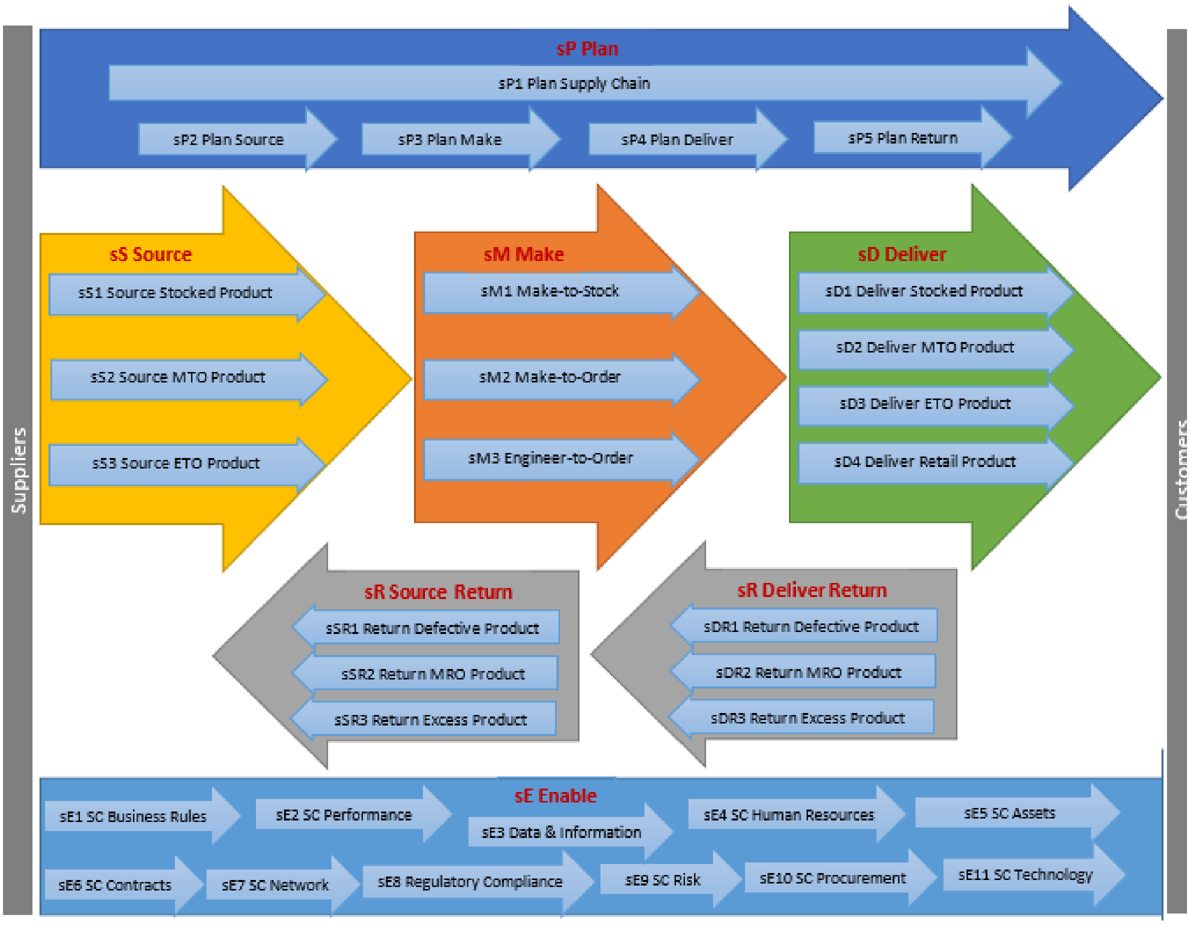
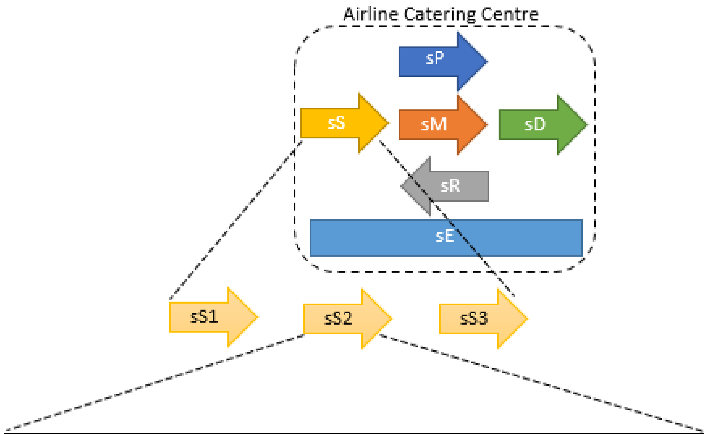


Figure 5.5 Level 2 process categories in SCOR model

Level 2 defines the key process categories that may serve as components of the supply chain, as illustrated in Figure 5.5. It is called as the configuration level. Organisations can configure their supply chain by choosing relevant processes among them. Level 3 of the reference model is called as activity level. Here, the process categories of the configuration level are further subdivided into subprocesses. The detailed process elements of the supply chain are defined at this activity level of the reference model.

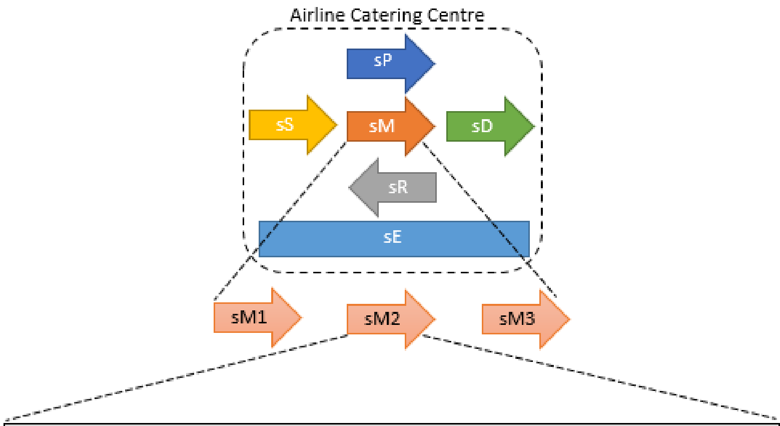
Each of the below diagrams shows the illustration of three different level 3 process elements relevant to this project. The three process categories chosen from the SCOR reference model to focus on the implementation of airline catering logistics execution are ‘Source MTO product’, ‘Make-to-Order’ and ‘Deliver MTO product’. Level 4 expansion into workflows is described in the case study section with the designed process models.



Level 3 process elements in sS2 process category (Source MTO Product)	
sS2.1 Schedule Product Deliveries	sS2.4 Transfer Product
sS2.2 Receive Product	sS2.5 Authorise Supplier Payment
sS2.3 Verify Product	

Figure 5.6 Level 3 process elements in sS2 process category

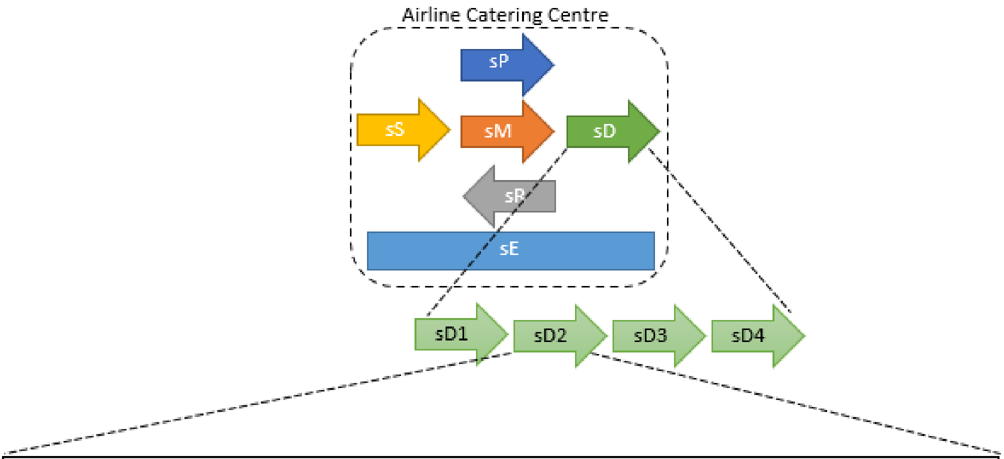
Source process consists of three core process categories in the Level 2 hierarchy of the SCOR reference model such as source stocked product (sS1), source make-to-order product (sS2) and source engineer-to-order product (sS3). In airline catering service industries, the procurement process of ordering and receiving meals and meal components takes place only when demand is required by a specific airline catering order. Therefore, Source MTO Product (sS2) is a more appropriate process category for the airline catering supply chain, and the Level 3 process elements of this category are illustrated in Figure 5.6.



Level 3 process elements in sM2 process category (Make-to-Order)	
sM2.1 Schedule Production Activities	sM2.5 Stage Finished Product
sM2.2 Issue Sourced/In-Process Product	sM2.6 Release Finished Product to Deliver
sM2.3 Produce and Test	sM2.7 Waste Disposal
sM2.4 Package	

Figure 5.7 Level 3 process elements in sM2 process category

Make process consists of three core process categories in the Level 2 hierarchy of the SCOR reference model such as make-to-stock (sM1), make-to-order (sM2) and engineer-to-order (sM3). In airline catering service industries, the creation of inflight products takes place for a given airline order. Tray sets and catering containers are assembled only in response to a specific airline catering order. Hence, Make-to-Order (sM2) is a more appropriate process category for the airline catering supply chain. ‘Assemble-to-Order’ is a similar term for ‘Make-to-Order’. Level 3 process elements of this category are illustrated in Figure 5.7.



Level 3 process elements in sD2 process category (Deliver MTO Product)	
sD2.1 Process Inquiry and Quote	sD2.9 Pick Product
sD2.2 Receive, Configure, Enter and Validate Order	sD2.10 Pack Product
sD2.3 Reserve Inventory and Determine Delivery Date	sD2.11 Load Product & Generate Shipping Docs
sD2.4 Consolidate Orders	sD2.12 Ship Product
sD2.5 Build Loads	sD2.13 Receive and Verify Product by Customer
sD2.6 Route Shipments	sD2.14 Install Product
sD2.7 Select Carriers and Rate Shipments	sD2.15 Invoice
sD2.8 Receive Product from Source or Make	

Figure 5.8 Level 3 process elements in sD2 process category

Deliver process consists of four core process categories in the Level 2 hierarchy of the SCOR reference model such as deliver stocked product (sD1), deliver make-to-order product (sD2), deliver engineer-to-order product (sD3) and deliver retail product (sD4). In airline catering service industries, the process of fulfilling airline catering service and delivering assembled inflight products are happening in response to a specific catering order from an airline. Therefore, Deliver MTO Product (sD2) is a more appropriate process category for the airline catering supply chain and the Level 3 process elements of this category are illustrated in Figure 5.8.

5.5 Case Study

This section describes the key findings of the case study analysis. It describes the specific characteristics of the airline catering logistics processes and the process sequence of airline catering operations that needs to be demonstrated by the business process model. It includes descriptions of the key issues confronting the operations process in its current state and also discusses the observation of airline catering logistics function.

5.5.1 Business Understanding

The applicability of the SCOR-based reference model was proven in a case study which involved a large airline catering organisation in the UK, which is referred to as company X. SCOR reference model has been used and further extended to design business process models for the airline catering logistics function of the company. Initial research has exposed that the majority of Company X's airline catering logistics functions are compartmentalised and isolated from one another. The advancements in technology and business changes like mergers and acquisitions led supply chain systems to remain in a diverse environment. Company X currently uses two primary non-integrated supply chain software systems, ERP and WMS, to support its logistics operations functions. These different applications employed in food assembly operations and warehouse operations serve specific departmental needs only. The same type of data is held in two disparate systems. Information exchange and sharing processes across the organisation seem inefficient. Company X currently utilises only specific aspects of both systems to manage its logistics functions. Both enterprise systems do not deal with all core industry-specific business functions. A considerable portion of the existing ERP system's functionality was left unexplored, and some parts are not used. The WMS was originally designed for specific warehouse processes, and the ERP system was customised for specific food assembly operations. The warehouse and food assembly operations processes have evolved without any significant changes or major updates in both the WMS and ERP system. These systems may be a limitation for further improvements in Company X's evolved logistics operations processes. This measure will result in an inefficient airline catering supply chain in the future.

From the case study investigation, some general weaknesses due to current system functionalities and the weaknesses due to the non-integrated system approach of Company X have been identified, which are listed below.

- Accommodating new customers is very difficult at this stage as it needs lots of customisation in existing enterprise systems. It was built to deal with the specific requirements of the current business.
- Additional labour resources are employed to maintain WMS processes. Due to the complexity of system processes and time constraints, more employees are required in warehouse operations than the actual requirement to complete the tasks.
- Increase in manual workload. Some business functions are isolated within the organisation due to two separate supply chain software systems deployed in the operations department, leading to the disintegration of information. The set of information related to business transactions resides in different locations of the company. Some information is shared and required by multiple departments, but it is not centralised and accessible through a single business information system. Employees are required to reproduce some information based on departmental requirements, resulting in additional effort.
- There is limited coordination between warehouse operations and food assembly operations as they rely on two isolated enterprise systems ERP and WMS. There is no clear information flow between the two operations areas regarding demand planning and supply capacity. There is no coordinated production planning on the shop floor.
- Dispatch constraints. As food and warehouse operations rely on separate information systems, there will be an incompatibility between information produced by both systems, almost having a chance to find errors at the last minute. Identifying and rectifying such issues is a time-consuming process. It might cause delays which have the highest cost impact on the service delivery.

In addition to these problems, there are some negative financial impacts of two non-integrated systems on the organisation. This is due to the additional investment cost, system maintenance cost, and labour cost to administer both systems.

Though highly sophisticated supply chain systems are used, Company X still operates in departmental silos. As a result of this, functional areas are also isolated in all aspects of the logistics service. The case study findings recognised that airline instructions and sharing of catering order details across food assembly and warehouse departments are extremely valuable to Company X. Allowing business processes to interoperate looks to be becoming increasingly relevant and necessary. The only way to mitigate this challenge is to redesign end-to-end logistics operations, from procurement, assembly operations, and delivery to airside. To achieve an integrated internal supply chain, Company X needs to digitally connect all the business processes.

5.5.2 Process Architecture and Mapping

This subsection establishes process architecture and mapping based on the case study. Process architecture is essentially a common and generally understandable view of all business processes that a company can carry out in order to provide a product or service to its customers and customers. In order to recognise the impact of BPI implementation, it is important to have a clear map of business processes from beginning to end (Panayiotou *et al.*, 2015). Thus, the effect can be analysed and understood before it is rolled out. The organisational unit, responsible departments, roles, participants, IT systems and documents in the business processes are usually identified in a process map. This is defined using a hierarchical approach (Okrent and Vokurka, 2004) and a perspective for the business process model that is understandable for everyone; business users, management and IT experts.

In this research, Process mapping outlines each step of the workflow activities for the logistics functional area of an airline catering organisation. This study adopts SCOR hierarchical process model to create a process architecture for the airline catering logistics business at the initial stage of process identification, as illustrated in Figure 5.9. The airline catering logistics process architecture consists of 4 level hierarchy of processes in an airline catering organisation: major processes, process categories, process elements, and workflow activities. Major processes and process categories are adopted from the SCOR reference model and case study findings. These are represented by value chain diagrams. End-to-end industry specific processes and workflow activities are documented using BPMN 2.0. Researcher used the Signavio Process Manager to map each process level and to model the core processes of the airline catering logistics function. BPMN is a graphical language that defines elements to model business processes and workflows (Polančič and Orban, 2019).

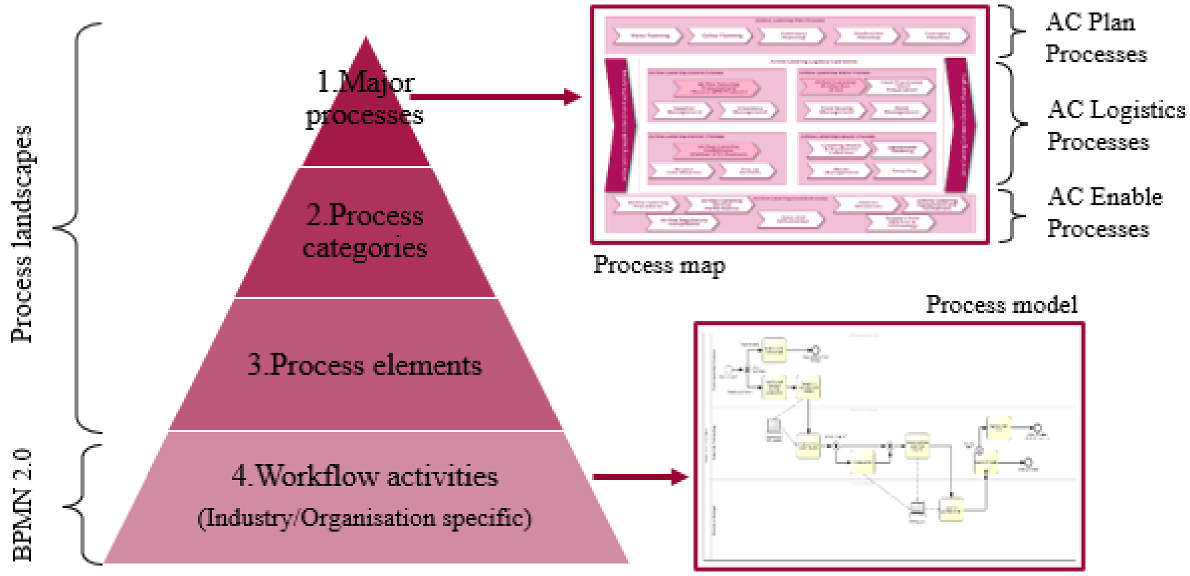


Figure 5.9 Process architecture - Airline Catering

From an architecture perspective, airline catering logistics is defined as the following major process areas.

- Airline Catering Procurement
- Airline Catering Production
- Airline Catering Fulfilment

The process architecture of the airline catering supply chain references how the airline catering logistics processes interact and perform and how the workflow activities are configured. First, major processes are recognised from the case study and are aligned with the SCOR model processes. Figure 5.10 shows the high-level process landscape of the airline catering operations.

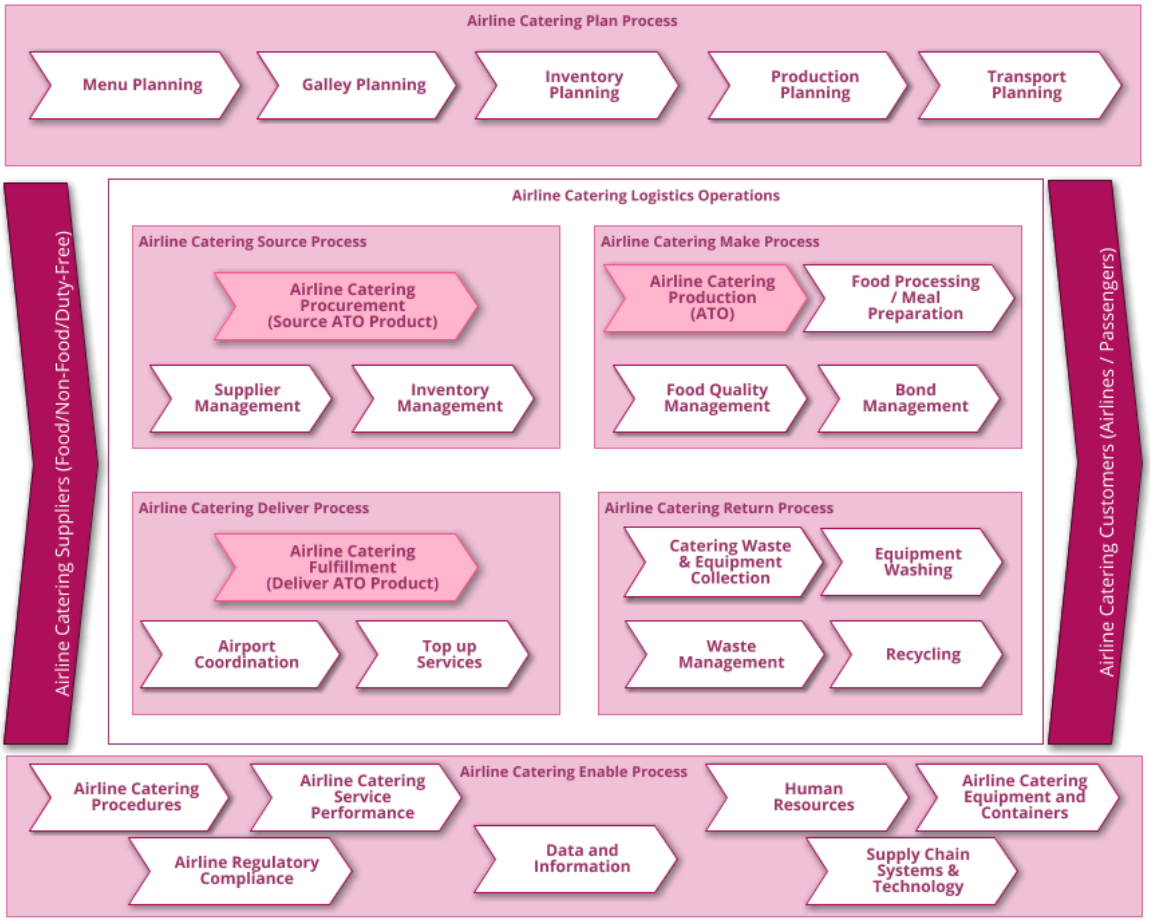


Figure 5.10 High-level airline catering process landscape

According to the SCOR reference model, there are six major business processes in the supply chain. These core processes, airline catering plan, source, make, deliver, return and enable processes, are included in the airline catering process landscape. Airline catering plan processes create plans to execute the airline catering supply chain. Airline catering logistics operation which covers the primary activities. Enable processes that enable the execution of these primary activities. The research has listed managing airline catering procedures, airline catering service performance, catering data and information, human resources, managing airline catering equipment and containers, managing airline regulatory compliance, and managing airline catering information systems and technology as such enable processes.

In airline catering service, logistics operations cover the main value creation of the airline catering supply chain: the source, assembly, and transportation of food, bar, and equipment items for which airlines pay. In this case study, research has identified airline catering procurement, airline catering production and airline catering fulfilment as the core logistics processes. Although managing the return flow of catering equipment and catering waste is part of the airline catering logistics operation, it is out of this project's scope for business process analysis and design.

5.5.3 Analysis and Design of Airline Catering Logistics

In this case study, researcher further extended the SCOR reference model to level 4 to design the business process model using airline catering specific processes and practices for airline catering logistics execution. This analysis and design section attempt to prescribe how an airline catering organisation should perform its logistics operations and can tailor the information flow within the enterprise system.

Logistics execution (LE) function of the airline catering organisation controls and coordinates the organisation's materials movement. It includes the outbound processing of despatching catering shipments, inbound processing of goods receipts of food and non-food items from the suppliers and monitoring the catering production and airline order fulfilment activities. LE function is the main component of the supply chain management application and allows airline catering organisations to monitor and control all the steps and processes that are involved in the supply chain. LE functionality will connect all the logistics processes that are part of the airline catering supply chain. These are external procurement, catering order processing as per the specifications, assembly of catering containers based on the catering instructions, storage of the assembled containers, managing inventory, delivery and loading of the catering products, management of catering sales details. The main functionality of LE is to focus on materials receipts, assembly of meals and bar, and processing airline orders. Without adopting an integrated information system, it would be laborious for an airline catering organisation to perform these tasks manually or using different tools. Besides, there would be the possibility of more manual errors, which can eventually be more costly in the airline business.

With the suitable process design, it is feasible to map all the logistics execution stages, from procurement of meals and other catering components to the final mile delivery of packed catering containers as assembled by the company. This will enable Company X to implement and configure an integrated LE system. According to the way this case study considered the design of the airline catering logistics operation, there are three core business processes included in the model: airline catering procurement (source); airline catering production (make); and airline catering fulfilment (deliver). These are illustrated in separate swim lanes in the core business process model, as shown in Figure 5.11. The process model for all the core logistic process cycles is redesigned, and interrelationships between the process model are established.

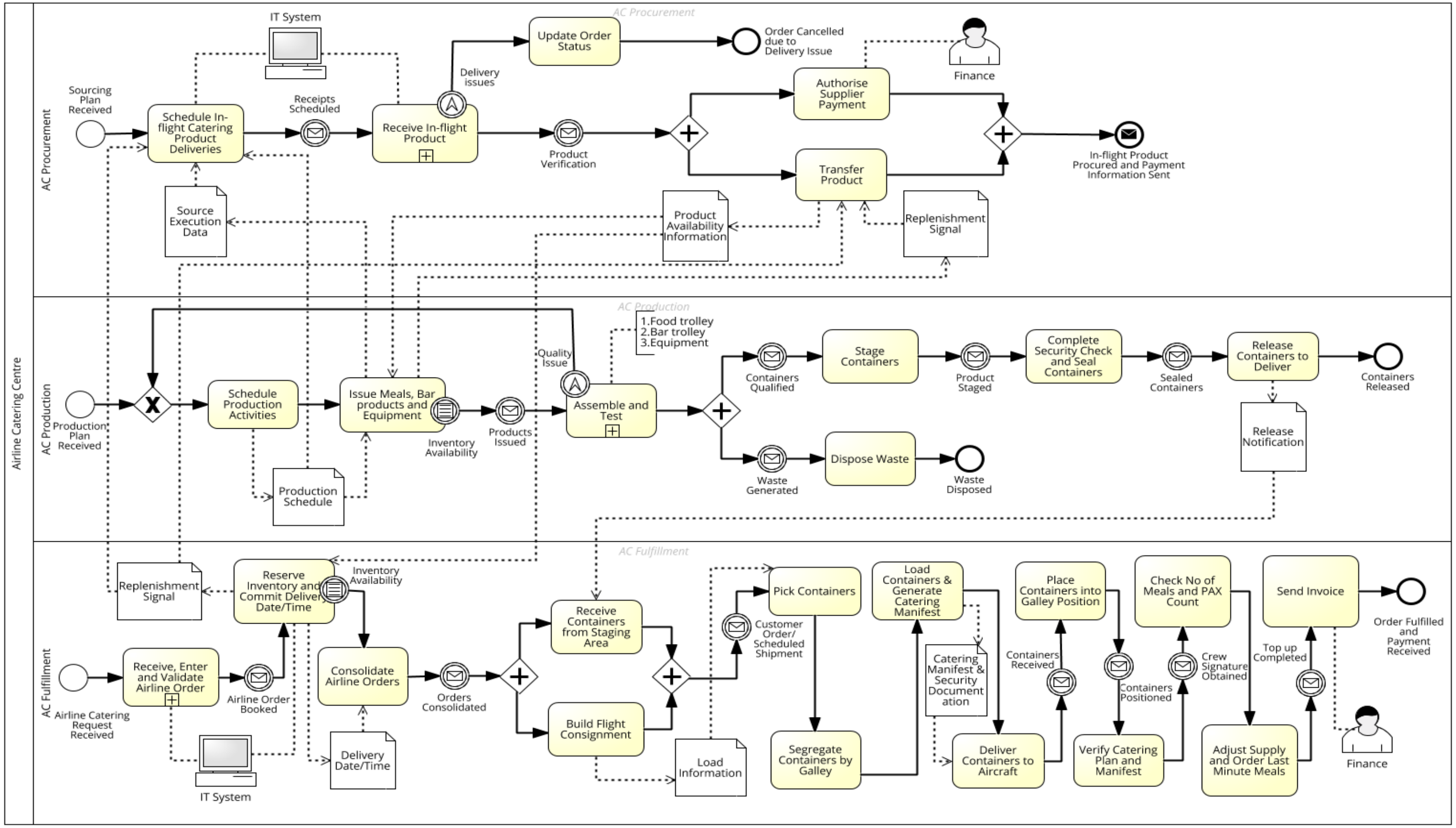


Figure 5.11 Core Business Process Model for Airline Catering Logistics

This model clearly indicates the branching in and out flows of processes and the integration not only streamlines internal processes but also facilitates the external connections with supplier and customer applications (possibility to see the passenger movements/meal provisioning/aircraft changes in real-time). It presents a set of specifications, business process models, data objects, and defines attributes that were produced as part of the process analysis being applied in logistics operations and, more specifically, in the airline catering business context described in this project. It provides transparency of process functions. All data and organisational elements are transparent. It represents all integrated activities, materials, and resources and shows the links between individual processes within and across the functional areas clearly.

The fundamental building blocks of the core business process model for airline catering logistics are derived from the level 3 process elements of the SCOR reference model (APICS, 2017) to design the main activity workflows, although some modifications were implemented. The core business process model consists of three horizontal swimlanes. It is a separate visual section of the model that shows different functional capabilities or department responsibilities. The first lane represents the airline catering procurement function performed in the service centre. This business case is adopted from the 'source MTO product' process category of the SCOR model. The middle swim lane illustrates the functionalities of the airline catering production which has been implemented from the 'make-to-order' variant of the SCOR reference model. The last swim lane covers the airline catering fulfilment function. The activities of this visual segment correspond with the generic process elements in the level 3 'deliver MTO product' process category of the SCOR.

Including the various swimlanes makes it feasible to visualise the information flows in conjunction with the control and coordination of integrated airline catering logistics execution. Interactions with other core processes (procurement, production and fulfilment) of airline catering logistics function in this diagram include the exchange of menu plans, catering production schedule, product availability information, replenishment signals for meal, bar and equipment items to be issued, aircraft galley plans, release notifications of completed airline catering containers and load plan information.

The core business process model can be expanded to many levels of subprocess diagrams. These subprocess diagrams are illustrated in Figure 5.12, Figure 5.13, and Figure 5.14. For example, anyone can zoom in on the "Assemble and Test" activity of the above discussed core business process model by clicking the plus sign of the task block.

Airline Catering Procurement – Source

Airline catering procurement includes functions associated with purchasing of, and pay for, all meals, food and non-food materials required by the airline order fulfilment process. There is one key variant to this core business process: supplier managed inventory of the airline's own stock, where the procurement is a predefined agreement for airlines to automatically send the airline catering company with the specific catering products and components under certain conditions triggered by average daily consumption and current stock level. The procurement business process covers all aspects of procuring meals and non-food items to stock. This includes activities such as raising a purchase order request, creating purchase orders, purchase order approval, receipt of items, and invoice verification. As an example, a sub-business process diagram for receiving airline catering products is shown in Figure 5.12

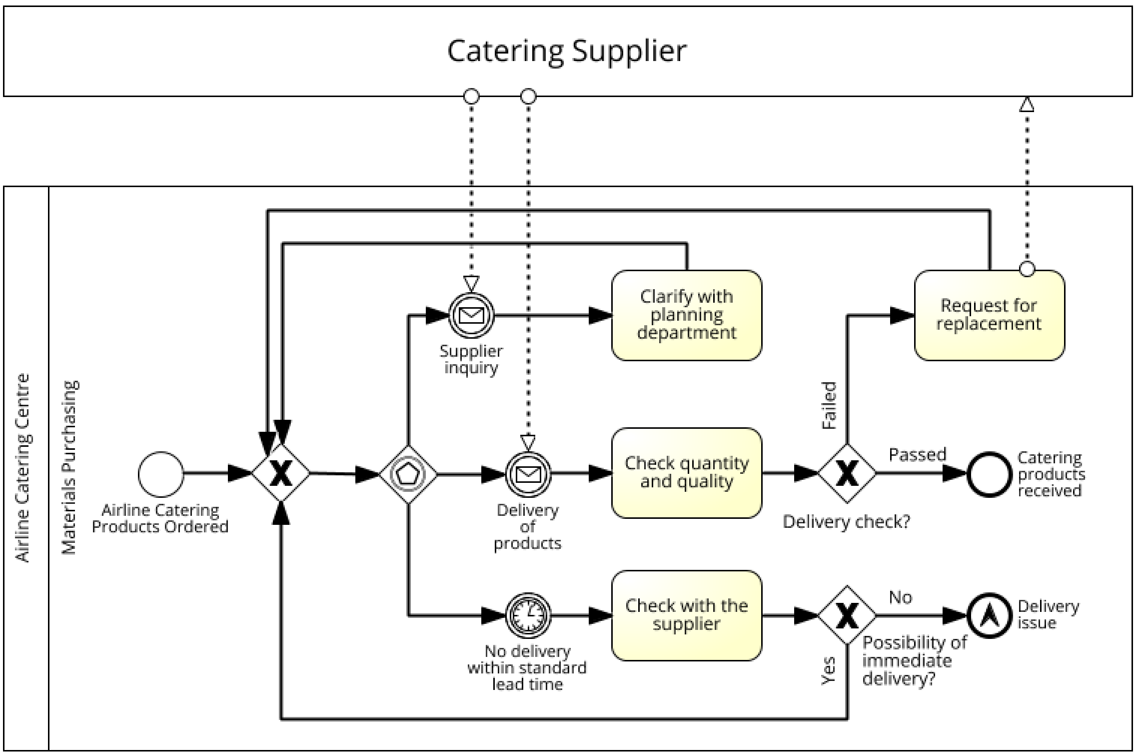


Figure 5.12 Sub-Business Process Diagram for Airline Catering Products Receipt

Airline Catering Production – Make

Airline catering production begins with the receipt of airline catering orders and ends with catering consignment packed for final mile delivery to the aircraft, as demonstrated in the separate swimlane in Figure 5.10. The main production method studied in this research to complete the production of different catering containers of in-flight products is assembly operation. In this method, meals and catering components are procured and put into inventory prior to the catering order from the airline being processed. The assembly process is executed when the actual catering order from an airline is received. The demand management procedures need to be defined to determine the appropriate production strategies that suit the airline catering company's business requirements best. Using the flight schedules and the forecast passenger demand, airline catering organisations can plan for a periodic meal demand (Hovora, 2001). The actual airline orders are then covered by this produced in-flight stock and procured materials. This allows operatives to make in-flight products as required and to replenish the catering containers in inventory. Airline catering production process covers all aspects of assembly operations, from materials planning, through production planning, to quality check, confirmation and inventory posting. Figure 5.13 illustrates the flow of all sub-processes in airline catering assembly operations.

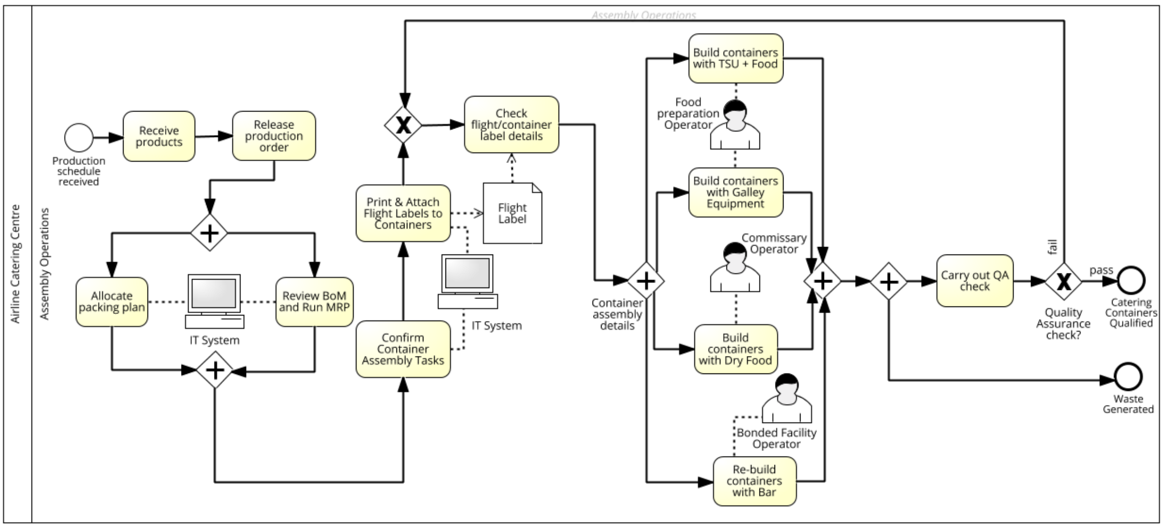


Figure 5.13 Sub-Business Process Diagram for Airline Catering Assembly Operations

The Make-to-Order process type of SCOR model, for instance, includes the following level 3 activities: schedule production activities, issue sourced product, produce and test, package, stage finished product, release finished product, and waste disposal. Based on the case study analysis of certain process characteristics in airline catering supply chains, the building blocks of core business process models and sub-business process diagrams are developed. In this case study example, there are no manufacturing activities in the service centre. Mainly the assembly operation is happening at the centre. Tasks like 'assemble and test' and 'complete security check and seal container' are more specific to the airline catering industry, which are included in the model. In addition to the quality assurance checks, complete security and food safety checks must be performed based on aviation regulations. Sub process of airline catering assembly covers more business specific activity flows such as aircraft galley plan, container packing plan allocation, run MRP (materials requirements planning) as per the menu plan's BOM (bill of materials), and container assembly details.

Airline Catering Fulfilment – Deliver

Airline catering fulfilment includes the steps required to complete the in-flight catering service. The following main steps are included in this process which can be seen in AC Fulfilment swim lane in Figure 5.11.

- begin with the determination of specified service offerings with meal types
- apply the suitable galley plan, and packing list to the airline order for consignment delivery to the aircraft
- settle with the airline payment for these catering products and services

This business process enables an airline catering company to efficiently deliver in-flight catering products directly from the service centre to the aircraft to meet airline demand. Airline catering fulfilment process involves numerous business activities – from airline order, catering service determination and galley plan allocation, and inventory management to catering consignment delivery and customer invoice creation. As an example, the airline catering order entry process is further expanded in Figure 5.14

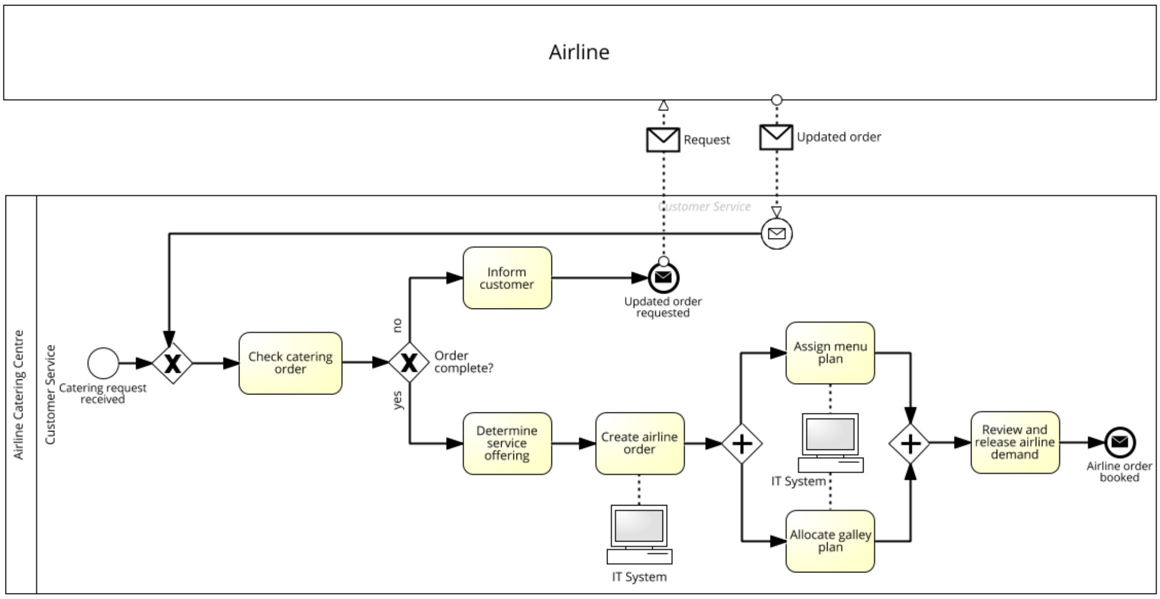


Figure 5.14 Sub-Business Process Diagram for Airline Catering Order Entry

5.5.4 Design Review

A design review is a process typically followed in software development. It is a systematic examination of a design to determine whether the given design requirements are appropriate and whether the design meets all of the business requirements. A project team can discover approx. 50 – 70 % of all design errors through a periodic design review in the early stage (Grady, 1992). According to the IEEE definition, a design review is a formal meeting that often entails the presentation of a proposed system design to a group of stakeholders at an early stage of the process to allow for necessary modifications and improvements (Thakur, 2022).

A focus group of experts based on the company was formed to critically examined the researcher's modelling efforts. The Focus group include a senior IS analyst, systems manager, process improvement champion, continuous improvement manager, senior operations managers, and planning manager. They have an average experience of more than ten years in the industry. The design review was done in two stages. First, a preliminary design review was held during the design phase, where the initial design was presented to the focus group to get comments related to high-level process architecture, BPI map and business process models. The focus group reviewed the initial design to ensure these conceptual models meet the business requirements, activity flows are captured, and effective modularity of logistics execution (procurement, production and fulfilment) are achieved in the design. There were no major faults identified in the proposed conceptual design, but useful comments such as including additional message flows, process conditions, and subprocess details were given for improvement.

In the second stage, a critical design review was conducted. The detailed design of the core business process model and subprocess models were presented by the researcher. He explained how the process design is meant to function at a high level. Researcher presented the BPMN diagrams and described them in sufficient detail to illustrate the essential design components. Some of the participants are process experts, and some have technical awareness. The focus group with mixed expertise was formed to ensure that the participants can express both the process and technical concerns with the process models during the critical design review. In addition to the overall high-level architecture, the focus group paid attention to the functional feature of the core process model. They looked at the design to ensure that the models comply with business process management (BPM) standards and confirm to the BPMN specifications. The ability of designed models to streamline internal processes and integrate internal information flow, and facilitate external connections with supplier and customer applications were discussed. The design has eliminated data and information repetition whenever possible, according to one of the comments from the focus group. This redundancy may result in inefficient use of resources and data inconsistencies between functional components. Additionally, they examined if all data and organisational elements are transparent. Does it represent all activities, materials, and resources that are integrated? Does it clearly illustrate the connections between various processes inside and across functional areas? Following the suggestion from the focus group, allocate packing plan and run MRP were designed to be executed simultaneously using a parallel gateway in order to generate the container assembly task list. Both activities are independent; packing plans related to aircraft allocation and MRPs are linked with flight schedules and menu plans. The container assembly task can only continue after both activities are completed, as the output of these activities needs to be cross-referenced to generate the container assembly task list that determines which meal components must be assembled into which catering container. This design review session ensured that all participants in the focus group were on the same page, understanding how the integrated logistics execution system will be structured and how its various modules will interact. The design review was beneficial for finding design flaws, improvements, and alternative approaches.

5.6 Discussion

The requirements analysis and business process design are effective in achieving the goals of developing business and functional systems requirements. Airline catering stakeholders and logistics professionals can easily understand and adopt this process analysis and design for customising, enhancing or implementing a logistics execution system for the airline catering business. This analysis approach uses the nontechnical language that is associated with the airline catering field. This is an important aspect of the effectiveness of process design. This enables accuracy and ensures no ambiguity when communicating the business needs and functional requirements to application developers as well as the software vendors of the logistics systems.

This study was intended to contribute to the development of SCOR based reference process models for the airline catering industry. There are some major contributions of this project that can be recognised. First, the research introduces a reference process model of reference for airline catering supply chains. To the researcher’s knowledge, such a model does not yet exist. The reference model combines airline catering specific information with generic supply chain standards. The project findings can support the expansion of the process-driven logistics functional areas and foster business process integration. It recommends a business process integration approach, proposes a business process modelling framework and develops business process models based on the SCOR framework to support the implementation of full-scale airline logistics functionalities at Company X to manage its increasingly complex logistics operations. Design and implementation of a new integrated solution for airline catering logistics operations based on the SCOR framework is an opportunity to bring Company X's food assembly operations and warehouse operations closer together in many ways. The results of this research study will enhance airline catering organisations’ understanding of conceptual and application issues of supply chain systems in the airline catering business environment, help optimise existing system deployments or implement an effective integrated solution for logistics execution to enhance operational excellence and resource efficiencies in the airline catering supply chain.

This study also contributes even more to the understanding of the role of enterprise systems in the airline catering industry. It identifies business processes in airline catering logistics that can be compatible with the enterprise systems as an integrated enterprise system should enable the airline catering organisation to work more efficiently. Thus, it can be used as a guideline for airline catering organisations who are looking to invest in enterprise systems. Furthermore, the proposed process architecture and business process modelling diagrams can be used as a reference for the configuration. This research study aims to support business processes integration of the airline catering organisation, particularly to enable the logistics execution to become more effective by designing its core processes within an information system context. The artefacts produced in this project are useful in communications between the airline catering organisations and the software vendors and developers of logistics execution systems. It is expected that the process map and models will help enterprise software developers to implement an effective integrated solution for logistics execution that can be tailored to the needs of airline catering supply chain industries. The process design can be used as a reference for assessing their existing logistics systems capabilities or customising and reconfiguring currently implemented solutions. For information technology professionals, the use of this business process analysis and design can be applied to various implementation projects to motivate the development of industry-specific, reusable logistics execution systems. Well-deigned and reusable industry sustainable, and scalable industry applications will reduce the total cost and shorten the implementation time associated with application development.

In addition, these process mappings and models provide the company with a fresh perspective for visualising innovative business models. It creates enthusiasm for continuous improvement by informing employees of the overall business context and objective of their functional area activity. Even the most efficient procedure can be ineffective if it does not bring value to the catering service as a whole. Before embarking on a large project of business process integration, organisations must first determine where the logistics process may be enhanced. Every interaction between the processes is involved with risk. In addition to the risk of failing to meet catering criteria, there is also the possibility that a non-compliant activity is being carried out. Business process mapping provides visibility into real-time decision making and fosters transparency around these process interactions.

Change management and communication are crucial during the phase of process modelling and implementation. The process landscape and designed models were made accessible to readers and commenters via a web-based collaborative platform. This allowed the entire organisation to be in agreement with the adjustments. Business users, management, and IT specialists who participated in the study evaluated the diagrams, reviewed them with their colleagues, and provided suggestions for enhancements. By validating the designed process models to streamline work processes in the airline catering operations, the management of Company X gained a thorough grasp of the efficacy of integrated business processes.

After the process mapping was completed and the process landscape was designed, it was decided to proceed to the specification of implementing one logistics execution system. Actual implementation and system validation are not within the scope of this project. This project focused only on the process design and leaving the detailed technical specifications for configuring or implementing the system to the airline catering company and IT service vendors. The actual system implementation will help Company X with real-time visibility to manage the operations performance effectively. The experts who participated in this study have recognised some benefits that the business process integration within one centralised information system can offer for the organisation to enhance the catering service efficiency as follows:

Real-time stock visibility and traceability - It will give the accurate stock level in real-time to react to changing airline requirements and make decisions about product substitution in case of any supplier issue. It will also allow the airline catering operation's team to trace any products or containers through the facility for any customer complaints or any other investigation purpose.

Improvement in labour productivity-Direct labour is the biggest cost in the airline catering business; cost per flight and cost per passenger are a few of the key performance measures in the airline catering supply chain. Effective process design within the airline catering logistics function will enable productivity measures for direct activities and will improve the efficiency of the operation.

Reduction in mis-picks- It will reduce the number of mis-picking containers and avoid loading of wrong type aircraft equipment.

Reduction in flight delays-It will help warehouse operatives to pick the right type and quantity of containers and transport loaders to load into the right aircraft in the right stowage locations at the right time.

More accurate reporting - It will facilitate more accurate reporting as by integrating end-to-end logistics processes, the information system can generate flight completions report, stock consumptions report, production volume report and food manifest.

Improvement in responsiveness – Business process integration would improve the caterer's responsiveness to the airline customer. It will enable catering service providers to respond and implement the aircraft catering instructions changes in a timely manner and also execute any contingency plans for some emergency situations such as weather disruptions, crew strikes, and airport closures.

Improved customer service- It will enable airline catering operations to provide the right meal service with the right quantities to the right flight at the right time.

Minimises paperwork- Business process integration would eliminate the unnecessary use of paper works as it will automate onboard logistics plans; there will be no need to print and follow the galley plans documents. Many quality-related checks and security audits can also be performed systematically.

The contribution of the airline catering supply chain to the airline's profit growth is significant. However, a number of airline catering companies appear deficient in providing value to their customers due to inefficient supply chain processes. The success of the airline catering supply chain correlates highly with the integrations of their supply chain processes. The supply chain should focus on logistics systems to integrate their business processes and improve efficiency (Li, Liu, *et al.*, 2006). This project establishes a framework of business process design to support BPI. It's a conceptual discussion about how to design integrated business process models for logistics executions system. The process design is slightly biased to fourth-party logistics service in airline catering particularly due to the requirements of Company X. But this system can offer the same benefits to all the airline catering organisations that manage the culinary aspects in-house with some level of configuration changes and customisation as per the business requirements. These airline catering logistics process models can be adapted to any organisation in the airline catering business environment. This study does not cover the technical specifications for a logistics execution system which are frequently used for designing and developing information systems. Airline catering professionals are encouraged to adapt or modify this project deliverable to meet business needs. They can modify the business process models by adding specific requirements or removing any logistics process elements that fall outside the scope of their service provisioning. With business process modelling, airline catering organisations can connect the links between the catering service requirements and the people, process and technology that enable the better service standard.

5.7 Chapter Summary

This study aimed to provide conceptual knowledge of business process integration for effective airline catering supply chain and logistical operations. It presents a SCOR-based reference model and designed business process models to support the successful business process integration for airline catering supply chain, as sustainable business process management is a key driver for competitiveness and economic performance in today's businesses.

The airline catering logistics process design presented in this chapter is comprised of high-level process architecture, business process models, and operational principles pertaining to how the airline catering company wants to integrate and manage logistics operations in the supply chain. This research project focused on integrating three important functional areas of logistics operations into a single solution for the execution of logistics operations. They are airline catering procurement (source), airline catering production (make), and airline catering fulfilment (deliver). This chapter describes the results of the analysis and design of business processes for each of these categories, as well as the discussion that follows.

6 Performance Metrics

6.1 Introduction

Airline catering businesses have challenges in implementing an effective supply chain, particularly under high uncertainty. In meeting service level objectives, it is vital for airline businesses to embed appropriate performance measurement strategies in their supply chain processes. Several models and frameworks have been developed for understanding and benchmarking supply chain practices. The most common is the SCOR model. Supply chain partners commonly use the model due to the measurable characteristics and actionable outcomes included in the framework to improve supply chain performance (Lu *et al.*, 2016).

Airline catering organisations must adapt the aspects of supply chain performance measures concerning emergencies such as the COVID-19 pandemic according to the dynamic of the aviation environment, business context, and catering service requirements. Disruptive events significantly impact financial and operational performance in the airline catering supply chain. The challenge for airline catering organisations is improving or developing new performance measures to warn of malfunction risks and better support decision-making in situations like the COVID-19 pandemic. Like many other enterprises, airline catering organisations also need to address questions such as "How to effectively use the supply chain performance measures in airline catering service during unexpected significant disruptions?" and "What performance metrics should be considered to measure airline catering supply chain performance during disruptive situations like COVID-19 pandemic?".

In an example case, a large airline catering supply chain in the United Kingdom is interested in exploring the choice of their performance metrics during the COVID-19 pandemic. The supply chain has a set of performance measures in place and would like to adopt the SCOR framework in order to improve its logistics service performance and the effectiveness of its catering operations. This is the focus of the research reported in this chapter, and the large airline catering supply chain is used as a case study. The SCOR model version 12 is adapted to develop supply chain performance measures for the airline catering supply chain. As part of the research reported in this chapter, the researcher worked with the case study organisation to develop performance metrics for the organisation's airline catering supply chain and analysed the performance metrics considerations of the case study organisation during the COVID-19 pandemic.

There are many evaluation models used for measuring supply chain performance. However, using the most effective one will ensure better outcomes. The Balanced Score Card (BSC), the European

Foundation for Quality Management (EFQM) excellence model and the Supply Chain Operations Reference (SCOR) model are a few popular performance measurement models (Fri *et al.*, 2019). BSC model comprises four areas: customer, finance, internal processes, innovation and growth. It supports the business strategy with balanced measures (Camilleri, 2021). The EFQM model is a general management model that highlights the crucial components of a business. it includes areas on human management and improvement, process efficiency, and continuous improvement. The EFQM model consists of nine criteria, which are solely separated into enabler and results categories (Fonseca, 2022). In contrast to the EFQM model, which is a general model and depicts key aspects of a corporation, the BSC supports corporate strategy with balanced measures. However, in comparison to the BSC and EFQM models, the SCOR model is more business process oriented. It also fulfils most of the critical requirements for performance evaluation for the end-to-end supply chain. Thus, the SCOR model is the most useful tool out of other performance evaluation models because it considers all critical supply chain management processes and takes into account all parties in the supply chain (Maizi *et al.*, 2020). As a result, processes could be adapted and enhanced through the sharing of best practises throughout the entire supply chain network. The objective of SCOR is to provide enhanced business process models for the supply chain that may be used in a number of industries and supported by a set of well-established performance metrics and best practises (Kottala and Herbert, 2019). The SCOR model was chosen for this study because it stands out among other models in terms of strength and usefulness for this particular area of the study. Complex business processes within the airline catering supply chain can be visualised as described in the previous chapter and studied using the SCOR model. SCOR performance metrics are closely connected with organisations' strategy. The common language established by SCOR through consistency and clear definition of metrics makes performance related communication easier (Lima-Junior and Carpinetti, 2020). SCOR performance metrics are well matched with the priority and objectives of the airline catering organisation that is used in this case study. SCOR model considers both performance and cost-relevant metrics which can be linked to the airline catering service strategy. Besides, SCOR-based performance measurement can be easily integrated with multi-criteria decision analysis to measure overall supply chain performance based on the relative importance of the five performance attributes and six primary management processes (Yuniaristanto *et al.*, 2020).

Following this introduction, the remainder of this chapter contains five sections. Section 6.2 provides the research methodology adopted in this project. Section 6.3 presents the airline catering SCOR model developed in this research and describes the adaptation and development of performance metrics for the airline catering supply chain used as the case study in this chapter. The case study and the results are described in section 6.4. The discussion of the results is presented in Section 6.5. The chapter summarises the key points in Section 6.6.

6.2 Methodology

A case study approach is adopted in this chapter. An airline catering service provider based in the United Kingdom, referred to in this chapter as Company X, participated in this case study. As mentioned in the previous chapter, the airline catering logistics processes of Company X were first directly observed, and an AS-IS business analysis of the company was conducted to understand the business processes of airline catering operations at a high level. In addition, operational practices of Company X were observed, including shop-floor operations in order to capture current supply chain processes in the warehouse, and the food assembly operations, at the company's airline catering service centre. Following an understanding of airline catering operations, a focus group that consists of ten senior supply chain management professionals in the case study organisation was formed. The participants were chosen for their expertise in the functional areas and in measuring the performance of airline catering supply chains. They were heads of departments and senior operations and supply chain managers. Each of the participants in this study had at least a minimum of ten years of relevant experience in the airline catering business, and the average overall experience was 11.5 years.

The case study research was done in three stages. First, the airline catering SCOR model was developed for Company X, focusing on the Level 1 strategic metrics and Level 2, 3 diagnostic metrics in the SCOR framework. The airline catering SCOR model developed was validated by the focus group participants. Second, the focus group prioritised diagnostic performance metrics, i.e., Level 2, 3 SCOR metrics. Finally, in the third stage, the focus group participants identified changes in their considerations of the performance measures as the result of the COVID-19 pandemic. The focus group participants also discussed the effects of the COVID-19 pandemic on the choices of their performance metrics.

The study was conducted mainly through semi-structured interviews and questionnaires. Semi-structured interviews were used in the first stage of the study to understand the airline catering logistics practices. The SCOR model offers more than 280 measures in total that are relevant to five performance attributes and six primary management processes. Based on information from the case study organisation, researcher has chosen all performance attributes and processes from SCOR. Researcher then examined the airline catering relevance of level 1,2 and 3 SCOR performance metrics under all performance attributes. Ten industry experts in the focus group rated the importance of each of the SCOR performance metrics for the airline catering supply chain using a scale of 1 to 5 (Criteria 1 = Not at all important, 2 = Slightly important, 3 = Important, 4 = Fairly important, 5 = Very important). At first, the performance metrics with an average score of more than three were filtered. Then, most appropriate metrics were chosen and adopted through a process of elimination. Researcher incorporated literature review, business insights from the focus group's operational experience, and their feedback based on airline catering practices into the metrics selection process. Researcher focused on high-impact metrics that can result in real benefits for the airline catering organisation during this process. A final set of 55 suitable performance metrics from SCOR framework was proposed for airline catering supply chain at the end of the first stage.

In stage 2, researcher prioritised the performance metrics to effectively implement during the COVID-19 pandemic using a questionnaire method. The final set of performance metrics proposed in Stage 1 includes 7 Level 1 metrics and 48 Level 2, 3 metrics. The seven Level 1 strategic metrics were all essential for measuring supply chain performance during the pandemic, according to focus group experts, who also admitted that not all 48 Level 2, 3 diagnostic metrics were equally important. The MoSCoW prioritisation approach was employed in Stage 2 of the investigation. MoSCoW was used in this study to answer the question: Which metrics are most vital to the effectiveness of the airline catering supply chain and which are less important during the COVID-19 pandemic? The MoSCoW prioritisation technique was applied in the questionnaire administered to the focus group participants to capture their perspectives on performance measure priorities. The MoSCoW method is one of the oldest and most promising prioritisation techniques commonly used in the software engineering discipline (Tufail *et al.*, 2019). It's very useful for the hierarchical classification of user requirements and prioritising them relatively fast (Beltman *et al.*, 2016). It's very important to get the MoSCoW definitions unambiguously with the stakeholders to avoid the results based on personal opinions and better align with the business goals. The letters (Mo, S, Co, W) of this prioritisation technique in this scenario are given in Table 6.1 below.

Table 6.1 Metrics prioritisation

Must have (Mo)	Non-negotiable metrics that are mandatory for airline catering supply chain/logistics performance measurement during the COVID-19 pandemic.
Should have (S)	Important metrics that are not vital, but add significant value for airline catering supply chain/logistics performance measurement during the COVID-19 pandemic.
Could have (Co)	Nice to have metrics that will have a small impact on airline catering supply chain/logistics performance if not measured during the COVID-19 pandemic.
Won't have (W)	Performance metrics that are not a priority for airline catering supply chain/logistics performance during the COVID-19 pandemic.

A questionnaire was given out to the ten supply chain experts in the focus group. In the questionnaire, 48 MoSCoW questions with respect to the previously defined Levels 2 and 3 performance metrics were formed. These MoSCoW questions were placed under the six process perspectives-Plan, Source, Make, Deliver, Return, and Enable. The respondents were asked to choose the category from MoSCoW classification to determine the priority for each metric. After the questionnaires were received from the respondents, the performance metrics were aggregated. The mean values of the metrics were derived and assigned to the relevant priority group.

In the third stage of this study, data was collected on performance considerations regarding the adaptation of performance attributes and supply chain processes during COVID-19 using a questionnaire. After proposing the metrics priority for the airline catering supply chain based on the investigation of the case study organisation, researcher then conducted a study on the performance consideration changes during the COVID-19 pandemic with the participation of ten supply chain experts. Knowing the criticality of measuring the airline catering supply chain during an emergency situation, researcher focused on two aspects of the investigation exercise, performance attributes and supply chain processes. Researcher used a Likert rating scale with seven responses (very high decrease, high decrease, little decrease, no change, little increase, high increase, very high increase) to assess the expert's opinion on performance consideration changes with the relevance of five performance attributes and six primary management processes.

6.3 Airline Catering SCOR Model

Airline catering logistics is the process of planning, implementing, and controlling the flow and storage of a vast amount of airline meals, beverages and catering equipment for all cabin classes along with crew meals from the kitchen to aircraft to meet the airline catering requirements. While airline catering logistics shares similarities with other commercial logistics services in the processes such as streamlining the supply chain activities, transporting goods and implementing a cost-effective operation, the airline catering business differs in its supply chain structure, stakeholders, operational environment, complexity, demand, and requirements. These unique characteristics make performance measurement in airline catering logistics more challenging. Logistics service providers in the airline catering supply chain manage a significant part of the entire supply chain and offer a complete airline catering solution. They deliver a range of solutions covering; planning and design, sourcing and supply management, assembly operations, airport operations, final mile delivery and returns management. They provide one-stop-shop catering services to airline customers.

Though the SCOR model has been applied widely in various industries to improve supply chain efficiency (Lemghari *et al.*, 2018), the application of this performance measurement model to the airline catering industry is limited. This chapter provides airline catering organisations, professionals, and supply chain researchers with baseline information on applying the SCOR model in the airline catering supply chain, with a focus on airline catering service requirements. Hence, the airline catering SCOR model attempts to recognise the association between the supply chain functions and the airline catering logistics challenges across all stages of the catering order fulfilment cycle. The airline catering operation defined in this research is based on the six primary management processes organised in the SCOR model: plan, source, make, deliver, return and enable (Delipinar and Kocaoglu, 2016).

These six core processes cover all phases in an airline catering supply chain, starting from catering orders sent by airlines to transactions of airline catering materials such as catering equipment, containers, meals and beverages; and interactions with airlines, suppliers and caterers in order to plan for catering demand and fulfil airline orders to the aircraft. By classifying the airline catering supply chain into these six primary processes, the airline catering SCOR model establishes a set of indicators that can assist in the measurement of airline catering supply chain performance.

While conducting the research study, the need to adapt the SCOR model to be applicable to the airline catering environment was realised. The current SCOR model was generic and did not directly cover all functions in the airline catering supply chain. The adapted version of the airline catering SCOR model is shown in Figure 6.1 and covers all supply chain activities involved in the airline catering environment under six management processes, namely, plan, source, make, deliver, return and enable. This model defines unique processes an airline catering supply chain requires to operate in order to achieve its primary goal of fulfilling airline catering orders.

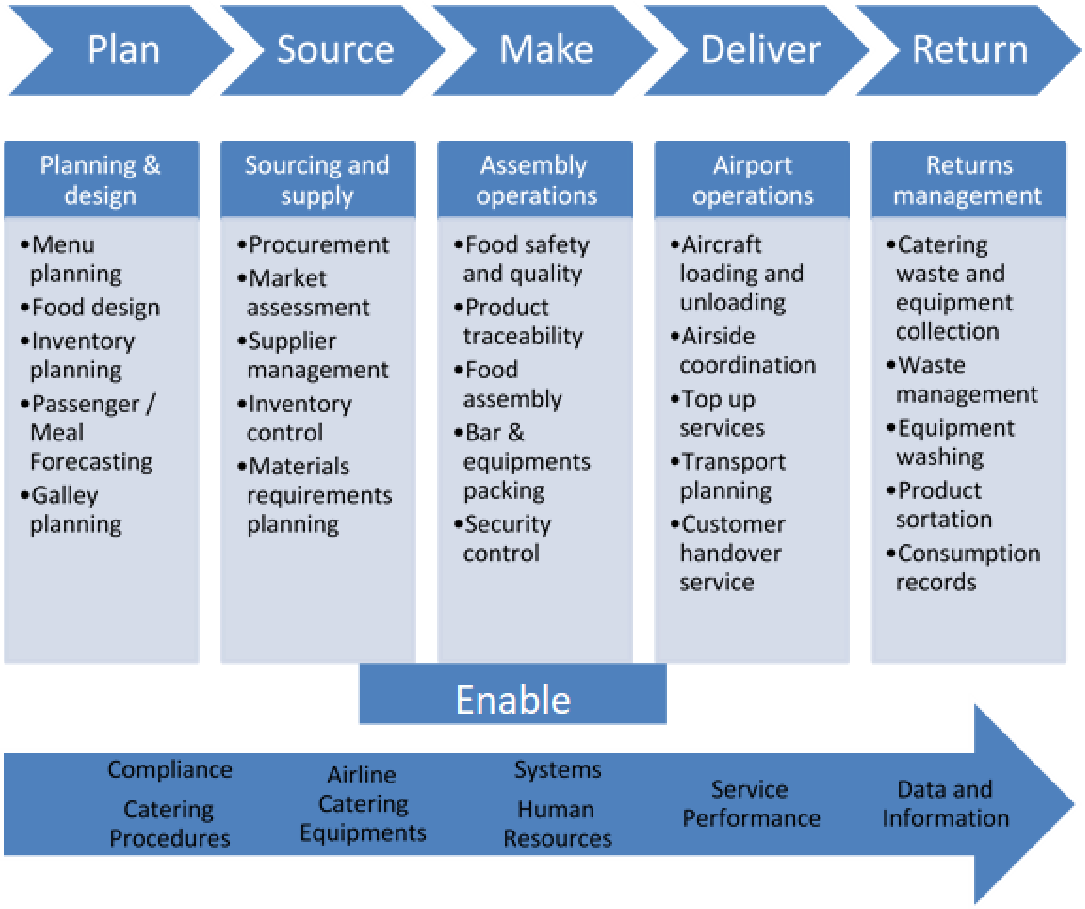


Figure 6.1 SCOR model of airline catering supply chain

Plan: The planning process of the airline catering SCOR model describes all the activities related to developing the plan for operating the airline catering supply chain. This process deals with collecting airline catering requirements, gathering available resource related information, and matching the demands with the resources to understand the gaps and operational capabilities. The organisation can decide what actions need to be taken to fill the gaps. As illustrated in Figure 6.1, one of the critical activities in the airline catering supply chain is menu planning. Airlines and caterers work together to meet the needs of onboard passengers. The other essential activity involves in this process is galley stowage planning. This has a significant influence on the design of inflight catering product specifications and menu planning. Highly volatile passenger numbers and consumption demand are making demand management more challenging. Accurate forecasting of passenger numbers and meal orders are critical aspects in this process to fulfil airline orders through the effective inventory planning function.

Source: The source management process includes all the activities involved in sourcing meals, beverages, ancillaries and packaging items from the suppliers and ordering or scheduling and receipt of any other rotable, consumable or disposable products owned by airlines such as catering containers, equipment and bar items. The organisation must have an engaging work relationship with many external suppliers to find the right products, both customers nominated products and sourced products to meet the customer expectations. This process includes determining catering order requirements, creating purchase orders or scheduling deliveries, receiving goods by checking the type of products and quantities against the purchase order, storing the goods in appropriate storage areas, verifying and accepting the invoice from the supplier.

Make: Make is the management process that describes the conversion activity of materials or creation of meal, bar and equipment content for airline catering service. The case study organisation has subcontracted the meal production activities. Hence, the research reported in this chapter focuses on assembly operations rather than manufacturing or production function, as there are no cooking activities on-site in Company X but outsourced to the food manufacturers and/or suppliers. In the above airline catering SCOR model, the make process represents a specific type of materials conversion, which is the assembly operation. This process takes one or more items as input and generates one or different items as output. In the example of the meal tray set assembly process, it consumes the main meal and various tray set components (jam, milk gigger, water couplet, salad and dessert). It then produces a complete tray set unit such as hot breakfast tray set, hot meal tray set or cabin/tech crew meal set. Flight schedule determines the production plan for the availability of inflight products and services (Hovora, 2001). ATO (Assemble to Order) production in this airline catering organisation means the components of the final catering products are assembled after the airline order is received, according to the catering requirements and appropriate specifications. ATO reduces the inventory required and quickly delivers the final product to the aircraft. In this airline catering environment, components are procured well before the airline order arrives, and some meals are already produced and ready to be assembled based on the specific catering requirements.

Deliver: The deliver process includes the management of airline catering orders and the transportation of the catering containers to the flights. It consists of all activities associated with creating, managing, and fulfilling airline catering orders. This process includes the receipt of all relevant information from airlines to process the catering order request, validating the information such as flight details, meal-type and quantities and creating the sales orders with reference to the catering request. It also covers scheduling outbound delivery, picking, preparing catering containers for shipping, the goods issue process and creating billing documents. Transportation of catering containers to aircraft is one of the core activities in the airline catering logistics service. Airline catering organisations need to ensure that the food is delivered to the right flight at the right time in appropriate conditions. Correspondingly, the timing of unloading the previously used catering containers from the aircraft (de-catering), loading the new catering containers (catering) for the next service flight and handover the fulfilled catering orders to the flight team with relevant documentation is critical to ensure everything is set and onboard for the departure of the flight without any delay due to the catering service.

Return: The return process defines all the activities involved in managing the reverse flow of catering equipment and waste from aircraft. On arrival, all the catering containers, equipment and catering waste will be collected from the return flights and transported back to the assembly centre. Catering waste will go through the waste management process. Containers and equipment will be washed and kept ready for reuse. Catering waste is caused by the inflight meals, beverages and snacks that are served to the onboard passengers. They are made up of leftover food, packaging materials and excess drinks. It can also include a large number of unused beverages, snacks and ice. The airline catering organisation collects, stores, and disposes the catering waste as part of its reverse logistics process and supports the airline in meeting its sustainability objectives. They are committed to minimising catering waste by analysing the passenger consumption data, reusing the catering equipment effectively, recovering and recycling untouched and non-perishable food items.

Enable: Enable process is the core of the SCOR model that defines all the business functions associated with managing the airline catering supply chain. These functions include business continuity management, dealing with aviation regulatory compliance, managing airline catering procedures, performance management, continuous improvement initiatives, and implementing sustainability strategies. As stated in the introduction chapter, airlines are struggling to maintain profit margins despite the growth in airline passenger numbers. Airlines are required to manage other operational costs, such as catering service costs, more efficiently to maintain sustainable airline operations. Airline catering organisations need to become more efficient in catering operations. Hence more focus is required on enabling processes.

6.3.1 Adoption of SCOR Performance Measures for Airline Catering Supply Chain

In this research, desirable performance metric characteristics for airline catering supply chains have been explored and derived from a review of the literature, SCOR framework, and airline catering business documents and reports to select a range of performance metrics for the airline catering supply chain. Some characteristics of good performance metrics related to supply chain management, with reference to airline catering supply chains, are listed in Table 6.2.

Table 6.2 Characteristics of effective performance metrics for adaptation in airline catering supply chain

Item	Characteristic	Description
1	Accurate	Able to project/calculate performance measure of activity accurately from underlying data without approximate and indistinct values (Thunberg and Persson, 2014).
2	Actionable	Employees able to take corrective action to improve performance (Suseno *et al.*, 2018).
3	Comprehensive	It covers all critical processes of airline catering operations (how well the inflight products and catering service is planned, sourced, made, delivered, and returned) (Lee *et al.*, 2017).
4	Diagnostic	Enable the organisation to analyse a performance issue and understand the causes of poor performance (Andi and Sisilia, 2019).
5	Informative	It should provide helpful information such as its origin, owner, time last reviewed and calculation methodology that a decision-maker can trust and use to quantify the performance outcome accurately (Dweekat *et al.*, 2017).
6	Industry-focused	Enables airline catering industry to express its current goals and objectives (Charkha and Jaju, 2014).
7	Practical	It must be updated regularly to ensure they drive the desired outcome and provide relevant and timely information (Chae, 2009).
8	Simple	Easy to understand and easy to describe to stakeholders regarding what's being measured, how it is calculated, what is the target (Gonzalez-Pascual *et al.*, 2021).
9	Standardised	The definitions of terms can be agreed upon by all parties, and that performance measures can be consistent, easily explored/understood at a different level of organisation (Sangwa and Sangwan, 2018).
10	Strategic	It contains a strategic goal and is designed to help the organisation correctly plan, monitor and adapt airline catering operations and service strategy (Sarjono and Khosasi, 2020).

The SCOR model provides a comprehensive approach to understanding and diagnosing supply chain performance by measuring and assessing the supply chain execution processes (Delipinar and Kocaoglu, 2016). The performance section of the SCOR framework consists of three elements. They are performance attributes, metrics and process maturity. A performance attribute is a classification of metrics that are used to define a specific strategy. SCOR model defines five performance attributes (Reliability, Responsiveness, Agility, Cost and Asset Management Efficiency) to measure and assess the outcome of supply chain execution. They can be applied in different industries to address specific supply chain performance concerns. The SCOR model's strategic characteristics help organisations align the supply chain performance with their business strategy (Girjatovičs *et al.*, 2018).

Table 6.3 Linking SCOR performance attributes with airline catering logistics performance

	Performance Attribute	**SCOR Attribute Definition**	**Associated Definition for Airline Catering Supply Chain**
Customer facing attributes	Reliability	The ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process.	Consistently fulfilling the airline orders right, service meets the catering requirements. The ability to cater the correct meal offering with the right quantity in the appropriate condition according to the catering specification and load onto the aircraft on time as per the flights' departure schedules.
	Responsiveness	The speed at which tasks are performed. The speed at which a supply chain provides products to the customer.	The consistent speed of providing the catering service to Airlines.
	Agility	The agility of a supply chain in responding to external influences and marketplace changes to gain or maintain competitive advantage.	The ability to respond to catering service requirements changes in the airline business environment.
Internal facing	Cost	The cost related to operating the supply chain processes. This includes labour costs, material costs, and	The cost associated with managing and operating the airline catering supply chain. The cost of catering, decatering flights and aviation

		management and transportation costs.	security compliance, as well as the catering equipment washup cost.
	Assets	The effectiveness of a supply chain in utilising assets to support demand satisfaction. It includes inventory reduction.	The ability to efficiently manage the airline catering equipment, inventory of meals and beverages in support of airline order fulfilment.

Table 6.3 above shows the performance attributes definition of the SCOR model and associates the attributes with the corresponding airline catering service definition that is used as the guide for creating measurable airline catering supply chain performance metrics. Each performance attribute in the model defines a strategic direction by grouping a relevant set of metrics. They are comprised of different levels of hierarchy under five performance attributes, as displayed in Figure 6.2.

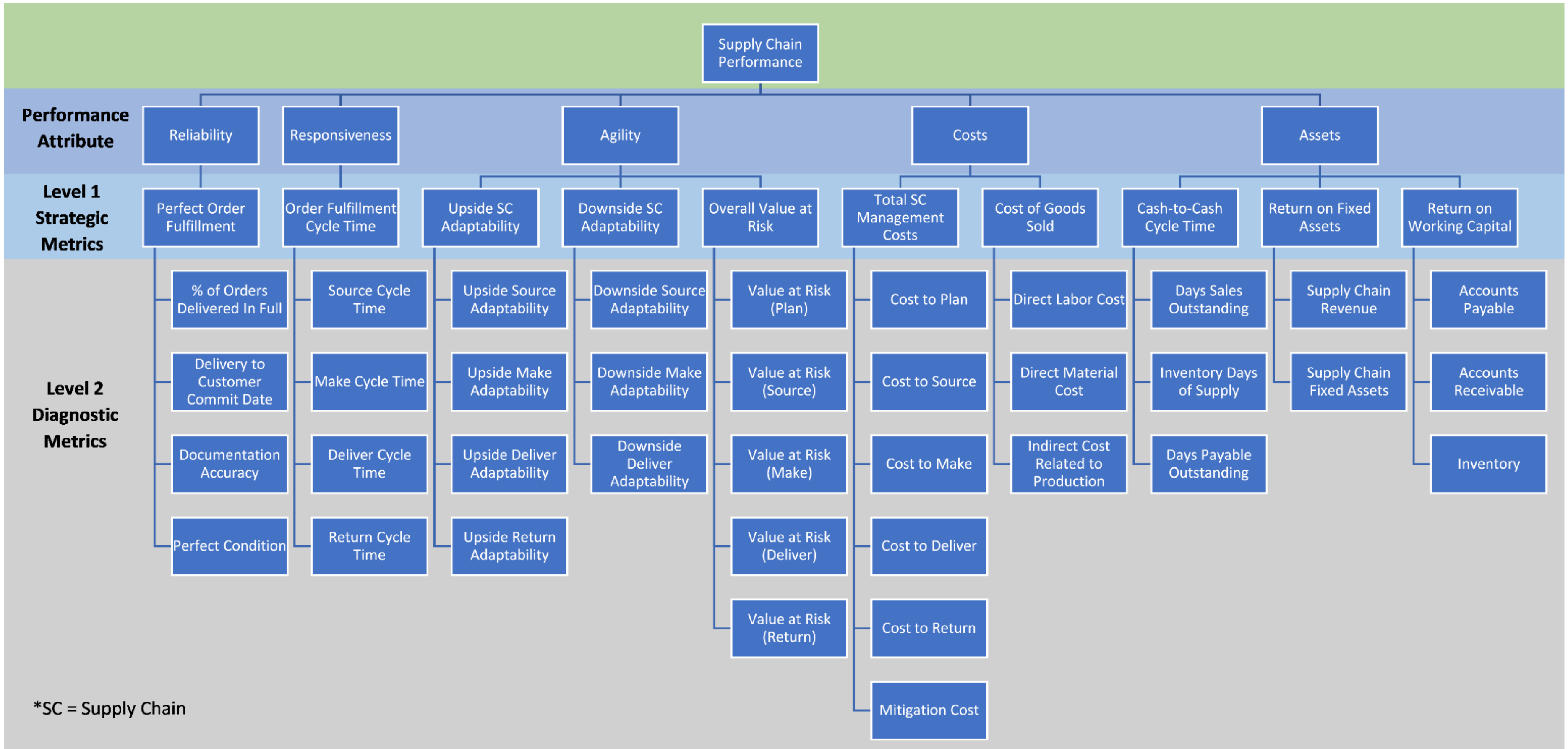


Figure 6.2 SCOR Level 1 and Level 2 Metrics

6.3.2 Performance Metrics Development

A performance metric is a standard for measuring the effectiveness of supply chain processes. Many organisations lack a clear vision to implement effective metrics for their supply chain performance (Kottala and Herbert, 2019). This research project developed related SCOR metrics for each of the five performance attributes recognised in the SCOR model. The performance attributes and their strategic metrics of the SCOR model are defined from the airline catering supply chain perspective as follows:

A. **Reliability:** Reliability is the customer focusing performance attribute, and it is an essential requirement for airline catering operations. The key performance indicator i.e. strategic (Level 1) metric for the reliability attribute, in the airline catering SCOR framework developed, is Perfect Order Fulfilment.

RL.1.1 Perfect Order Fulfillment: It is defined as the percentage of catering orders which meets the airline catering requirements. It measures the accuracy of catering services and the quantity. It measures whether all meals and bar service ordered are correctly delivered, and no substitutions or additional items are provided. All meal quantities delivered to the flight should match the catering order quantities as per the passenger number and agreed provisioning.

The next level diagnostics metrics of reliability attribute help assess the timeliness and conditions of the catering service delivery. Delivery performance to the airline commit time is the key aspect of logistics service provision in airline catering. From a timing perspective, the catering service delivery performance is based on the service commitments agreed between the airlines and the catering service provider. The customer commit time of an airline order is achieved when the order is delivered to the correct flight, and catering containers are loaded onto the aircraft on time prior to the flight departure. The acceptable timeframe before the scheduled time of departure for delivering catering orders should be defined in the service contract. Perfect delivery condition is measured at the airline order level, and evaluates the quality of the catering products delivered through the airline catering supply chain from the airline's perspective. It defines as the percentage of catering orders delivered in an undamaged condition, meeting catering specifications, catering containers and tray sets have the correct configuration, products are assembled in correct containers and containers are stored in correct stowage locations in the aircraft galleys.

B. Responsiveness: Responsiveness is also a customer focusing performance attribute in the airline catering supply chain and another essential requirement with the 'Airline Order Fulfilment Cycle Time' metric defined as its strategic metric.

RS.1.1 Order Fulfillment Cycle Time: The regular actual duration steadily taken to fulfil an airline catering order. For each flight order, the cycle time counts from the catering order receipt until the delivery of the airline order to the flights. It covers various airline catering supply chain activities to complete the order, such as sourcing products, assembly of catering orders and final mile delivery. Deliver cycle time is one of the diagnostic metrics for this key performance indicator, which is more associated with airside operations and covers the time allowed to decatering and catering the flight. This is the average time usually achieved to remove all used catering containers, collect catering wastage from the return service flight, load the new catering containers, and securely position them in appropriate aircraft galley locations for the next service flight.

Besides various cycle times defined in next-level metrics for order fulfilment as illustrated in Figure 6.2, some airline customers may want to monitor 'catering service inquire answering time', and 'catering issue resolution time' within the responsiveness attribute. Time is critical in the airline catering logistics process, and it's essential to respond to any catering related queries as soon as possible. These queries are usually related to the final quantities of various products in the order and the stowage position of different catering containers that includes specific products such as special meals or crew meals. Catering issue resolution time refers to how long it takes from the time a catering service-related issue is raised until the catering service provider gives the resolution. The common airline catering service issues include meal shortages, flight staff not being able to find a catering container or additional meals required due to last-minute upgrades.

C. Agility: Agility is also a customer focus performance attribute. The key performance indicator for Agility in airline catering SCOR is 'Adaptability', and it measures the ability to react to external factors. It includes any non-forecastable increase or decrease in catering demand that requires the ability to change the service level with speed and accuracy. An increase in passenger numbers causes meal shortage, and the decrease leads to meal wastage. Agility is critical in airline catering operations. Airlines catering organisations face volatile passenger demand and need to adjust their catering service rapidly according to the ever-changing and time-sensitive airline environment. A specific time frame for catering service amendments needs to be agreed upon between airlines and catering organisations. It is defined as the number of hours airline catering organisations require to achieve any unplanned service change. Catering service amendments are inevitable due to flight schedule time changes or aircraft type changes. These changes are significant as catering organisations need to provide a different menu entirely for all the passengers or have to reassemble and repack for different aircraft equipment types completely. These types of changes are infrequent, and catering service providers should be flexible in completing any level of service changes or catering requirements changes within the given period.

AG.1.1 Upside Supply Chain Adaptability: The maximum sustainable percentage increase in meal order quantities that can be managed in a specific time window. It is defined as the number of days or hours required to accomplish the volatile change in the meal quantity ordered. This time frame can be varied for different types of meals, such as standard passenger meals, crew meals and special meals.

Flexibility in the development of new catering products and services is critical for upside airline catering supply chain adaptability. This is defined as the regular average duration required to develop a new level of service or catering product. For each seasonal or special menu, the development period begins with the menu profile receipt and ends with the delivery of a new menu order to the flights. It represents all the time associated with various activities to develop a new level of service, such as sourcing products, pricing, getting final cost approval, IT system configuration changes, and order fulfilment of new service.

AG.1.2 Downside Supply Chain Adaptability: This defines the sustainable reduction in meal quantities ordered at a specific period without incurring inventory of meals and cost penalties. Flight delays and cancellations due to bad weather are common reasons for airlines to reduce airline order quantities. This will lead to airline food waste, which is a critical sustainability issue that many airlines are dealing with currently. This performance measure helps airlines and catering companies responsibly react to internal and external events and control catering waste. Some meals can be frozen or donated to food banks to reduce food waste. But, it’s not always possible since most airline meals are cooked freshly, unique timing requirements of airline catering service, airline catering equipment shortages, and the complexity of airline catering logistics.

AG.1.3 Overall Value-at-Risk (VaR): This risk metric helps organisations to assess the supply chain risks based on historical events. Airline catering organisations need to be aware of any events that potentially disrupt the airline catering supply chain and understand the catering service's risk exposure. It’s calculated using the probability of risk events and the monetary impact of the events that may affect the catering service. Measuring this risk metric can enable airline catering companies to mitigate or respond effectively to airline disruptions.

To facilitate performance improvement in the airline catering supply chain, it's important to identify best practices and examples of best-in-class catering logistics performance from historical events to deal with major disruptions due to heavy snow, volcanic ash, terrorism, and security threats pandemic. This measure helps determine how well airline catering organisations support airlines in dealing with disruption events.

D. **Cost:** One of the internal-facing performance attributes in the model is the cost which is a crucial element in airline catering operations as airlines are facing high-cost pressure, tightening the profit margin for airline catering companies. The airline catering SCOR key performance indicators for cost include the 'Total Airline Catering Supply Chain Management Cost' and the 'Cost of Meals Sold'.

CO.1.1 Total SC Management Cost: The sum of the cost associated with managing the overall airline catering logistics service. Further decomposition of this metric in levels 2 and 3 defines the costs of managing procurement, inventory, assembly, transportation, delivery, and cleaning processes.

Since airline catering organisations tend to hold supplementary stock for agile and responsive logistics execution, they need to find a balance between operating costs and supply chain risk. Inventory management cost covers all costs related to renting storage facilities, warehouse operations and relevant labour costs. Supply chain management cost also includes the mitigation cost associated with managing the supply chain risks arising from special events and unpredictable situations within the airline catering supply chain and covers other managed service costs. For example, the cost linked with monitoring the performance of different stakeholders in the airline catering supply chain such as food, and non-food suppliers and manufacturers and aviation security compliance monitoring cost related to the activities planned to comply with prescribed security regulations enforced by the aviation authority.

CO.1.2 Cost of Goods Sold (COGS): Cost of raw material, packaging items and food preparation costs are generally accounted for in the cost of the meal offering. It is recognised that there is a possibility to be an overlap between meal preparation cost and operational cost. It defines the cost associated with the cooking process and does not cover the cost related to assembly or other meal handing processes.

E. **Asset Management Efficiency:** Asset management efficiency is an internal-facing performance attribute that measures how efficiently the airline catering organisation utilise the assets efficiently. Inventory reduction of airline catering equipment and catering products is the key asset management strategy in the airline catering supply chain.

AM.1.1 Cash to Cash Cycle Time: For airline catering service, this represents the time from when an airline catering company pays for the resources used to provide the inflight catering service until the company has received payment from the airlines for the catering service. It is measured by calculating 'inventory days of supply', 'days outstanding receivable', and 'days outstanding payable'. This information is generally stored in enterprise systems. Inventory days of supply in the airline catering supply chain can be defined as the average period that it takes for airline catering organisations to utilise their entire inventory of inflight catering stock such as meals, bar items, tray set components, ancillaries other packaging items to cater the flights. This metric measures the average time between the receipt of stock from the caterers and suppliers, and the delivery of catering products to the flights.

AM.1.2 Return on Fixed Assets: This metric measures an airline catering company's return on its invested capital in fixed assets used in the airline catering supply chain. This includes all fixed assets that an airline catering company owns and uses for its primary management functions: plan, source, make, deliver, and return.

AM.1.3 Return on Working Capital: It is a supply chain performance measurement that assesses how efficiently the airline catering company generates revenue from the airline catering supply chain compared to its working capital position. This metric uses various components like airline catering supply chain revenue, the total cost to serve the flight, inventory, accounts receivable and accounts payable to calculate the performance measure. The inventory value of meals and other catering supplies is defined as the amount of meal stock and other catering supplies inventory calculated in currency value at the end of each accounting period.

Table 6.4 Proposed SCOR metrics for the airline catering supply chain. Adapted from SCOR Model Version 12.0 (APICS, 2017)

Metric No	Metric	Performance attribute and process	Definition
AC_RL.1.1	Perfect Order Fulfillment	Reliability and All Processes	The percentage of orders meeting delivery performance with complete and accurate documentation.
AC_RL.2.1	% of Orders Delivered in Full	Reliability and Deliver	Percentage of orders which all of the items are received by customer in the quantities committed.
AC_RL.2.2	Delivery Performance to Customer Commit Date	Reliability and Deliver	The percentage of orders that are fulfilled on the customer's originally committed date.
AC_RL.2.3	Documentation Accuracy	Reliability and Deliver	Percentage of orders with on time and accurate documentation.
AC_RL.2.4	Perfect Condition	Reliability and Deliver	Percentage of orders delivered in an undamaged state that meet specification.
AC_RL.3.1	Delivery Item Accuracy	Reliability and Deliver	Percentage of orders in which all items ordered are the items actually provided, and no extra items are provided.
AC_RL.3.2	Delivery Quantity Accuracy	Reliability and Deliver	Percentage of orders in which all quantities received by the customer match the order quantities.
AC_RL.3.3	Customer Commit Date, Time Achievement	Reliability and Deliver	Percentage of orders which is received on time as defined by the customer.
AC_RL.3.4	Delivery Location Accuracy	Reliability and Deliver	Percentage of orders which is delivered to the correct location and customer entity.
AC_RL.3.5	Compliance Documentation Accuracy	Reliability and Make	Percentage of compliance documentations are complete, correct, and readily available.
AC_RL.3.6	% Orders/lines received damage free	Reliability and Source	The number of orders / lines that are processed damage free divided by the total orders / lines processed in the measurement period.
AC_RL.3.7	% Item Location Accuracy	Reliability and Deliver	Percentage of item location accuracy.
AC_RL.3.8	% Orders/ Lines Received On-	Reliability and Source	Number of orders / lines that are received on- time to the demand requirements divided by the total orders

	Time to Demand Requirement		/ lines for the demand requirements in the measurement period.
AC_RL.3.9	% Orders/ lines received with correct content	Reliability and Source	Percentage of orders or lines received that have the correct material content as specified in the product design specs and supplier agreements.
AC_RL.3.10	Forecast Accuracy	Reliability and Plan	Common calculation (Sum Actuals - Sum of Variance) / Sum Actuals to determine percentage error.
AC_RL.3.11	Schedule Achievement	Reliability and Make	The percentage of time that a plant achieves its production schedule.
AC_RL.3.12	Yield	Reliability and Make	The ratio of usable output from a process to its input.
AC_RS.1.1	Order Fulfillment Cycle Time	Responsiveness and All Processes	The average actual cycle time consistently achieved to fulfill customer orders.
AC_RS.2.1	Source Cycle Time	Responsiveness and Source	The average time associated with Source Processes.
AC_RS.2.2	Make Cycle Time	Responsiveness and Make	The average time associated with Make Processes.
AC_RS.2.3	Deliver Cycle Time	Responsiveness and Deliver	The average time associated with Deliver Processes.
AC_RS.2.4	Return Cycle Time	Responsiveness and Return	The average time associated with Return Processes.
AC_RS.3.1	Current logistics order cycle time	Responsiveness and Deliver	Current logistics order cycle time, including customer order processing cycle time, dock-to- stock cycle time, pick-to-ship cycle, transit time, etc.
AC_RS.3.2	Establish Delivery Plans Cycle Time	Responsiveness and Plan	The average time associated with establishing and communicating deliver plans.
AC_RS.3.3	Establish Production Plans Cycle Time	Responsiveness and Plan	The average time associated with establishing and communicating production plans.
AC_RS.3.4	Establish Sourcing Plans Cycle Time	Responsiveness and Plan	The average time associated with establishing and communicating source plans.
AC_RS.3.5	External Event Response (average days)	Responsiveness and Enable	The average response time (in days) to an external risk event from the time of the event.
AC_RS.3.6	In-stock %	Responsiveness and Deliver	Percentage of materials, components, or finished goods that are there when needed.

AC_RS.3.7	Receive Excess Product Cycle Time	Responsiveness and Return	The average time associated with receiving excess product returns from the customer.
AC_AG.1.1	Upside Supply Chain Adaptability	Agility and All Processes	The maximum sustainable percentage increase in quantity delivered that can be achieved in 30 days.
AC_AG.1.2	Downside Supply Chain Adaptability	Agility and All Processes	The reduction in quantities ordered sustainable at 30 days prior to delivery with no inventory or cost penalties.
AC_AG.2.1	Upside Adaptability (Source)	Agility and Source	Maximum sustainable percentage increase in raw material quantities that can be acquired/ received in 30 days.
AC_AG.2.2	Upside Adaptability (Make)	Agility and Make	The maximum sustainable percentage increase in production that can be achieved in 30 days.
AC_AG.2.3	Upside Adaptability (Deliver)	Agility and Deliver	The maximum sustainable percentage increase in quantities delivered that can be achieved in 30 days.
AC_AG.2.4	Downside Adaptability (Source)	Agility and Source	The raw material quantity reduction sustainable at 30 days prior to delivery with no inventory or cost penalties.
AC_AG.2.5	Downside Adaptability (Make)	Agility and Make	The production reduction sustainable at 30 days prior to delivery with no inventory or cost penalties.
AC_AG.2.6	Downside Adaptability (Deliver)	Agility and Deliver	The reduction in delivered quantities sustainable at 30 days prior to delivery with no inventory or cost penalties.
AC_AG.3.1	% of labor used in logistics, not used in direct activity	Agility and Deliver	Percent of labor used in logistics, not used in direct activity.
AC_AG.3.2	% of labor used in production, not used in direct activity	Agility and Make	Percentage of labor used in production, not used in direct activity.
AC_CO.1.1	Total SC Management Cost	Cost and All Processes	The sum of the costs associated with the processes to Plan, Source, Make, Deliver, and Return.
AC_CO.1.2	Cost of Goods Sold	Cost and All Processes	The cost associated with buying raw materials and producing finished goods.
AC_CO.2.1	Cost to Plan	Cost and Plan	The sum of the costs associated with Plan.
AC_CO.2.2	Cost to Source	Cost and Source	The sum of the costs associated with Source.

AC_CO.2.3	Cost to Make	Cost and Make	The sum of the costs associated with Make.
AC_CO.2.4	Cost to Deliver	Cost and Deliver	The sum of the costs associated with Deliver.
AC_CO.2.5	Mitigation Cost	Cost and Enable	The sum of the costs associated with managing non-systemic risks that arise from special cause variations within the supply chain.
AC_CO.3.1	Direct Material Cost	Cost and Enable	Direct cost spent on material for production.
AC_CO.3.2	Indirect Cost Related to Production	Cost and Enable	Indirect cost spent incurred in production indirectly.
AC_CO.3.3	Direct Labor Cost	Cost and Enable	Direct cost spent on production labor.
AC_AM.1.1	Cash to Cash Cycle Time	Asset Management and All Processes	The time it takes for an investment made to flow back into a company after it has been spent for raw materials.
AC_AM.2.1	Inventory Days of Supply	Asset Management and Plan	The amount of inventory (stock) expressed in days of sales.
AC_AM.3.1	Percentage Excess Inventory	Asset Management and Return	The value of excess inventory as a percentage of the value of total inventory.
AC_AM.3.2	Capacity Utilisation	Asset Management and Enable	A measure of how intensively a resource is being used to produce a good or service.
AC_AM.3.3	Rebuild or recycle rate	Asset Management and Return	Number of returned products that are rebuilt or recycled as a percent of the total number of products returned.
AC_AM.3.4	Return Rate	Asset Management and Return	Quantity of products returned divided by the quantity of products shipped.

This research has developed measurable logistics service metrics applicable to the airline catering supply chain for each catering SCOR service performance attribute, as shown in Table 6.4. The developed metrics categorised into relevant performance attribute classes demonstrate a specific strategy. These metrics measure the capabilities to achieve the strategic objectives of logistics service provision in airline catering.

6.4 Case Study & Results

Figure 6.3 shows the priority groups for the fifty-five performance metrics presented in Table 6.4, based on the perspectives of the focus group participants. It excludes the strategic metrics as Company X recognised all Level 1 metrics are essential. The priority groups correspond to the four MoSCoW quadrants of Must-have (Mo), Should-have (S), Could-have (Co), and Won't-have (W). The first group, the Must-have quadrant, in Figure 6.3, consists of the most vital metrics for performance measures during COVID-19. It includes four metrics on Reliability, four metrics on Responsiveness, two on Agility, two metrics on Cost, and one on Asset Management Efficiency. The focus group participants also recognised another set of 15 metrics in the next group, the Should-have quadrant, in Figure 6.3, to add significant value for airline catering supply chain and logistics performance measurement during the COVID-19 disruptive period. The third group, the Could-have quadrant, in Figure 6.3, consists of 15 metrics considered desirable KPIs but have a smaller business impact when they are not implemented. Finally, the last group, the Won't-have quadrant, in Figure 6.3, consists of five metrics that are perceived not to be a priority for the airline catering supply chain and logistics performance during the COVID-19 pandemic.

Figure 6.3 Priority Groups for the Performance Metrics

Figure 6.4 below shows how performance measurement considerations regarding performance attributes have changed for the case study airline catering organisation during the COVID-19 pandemic.

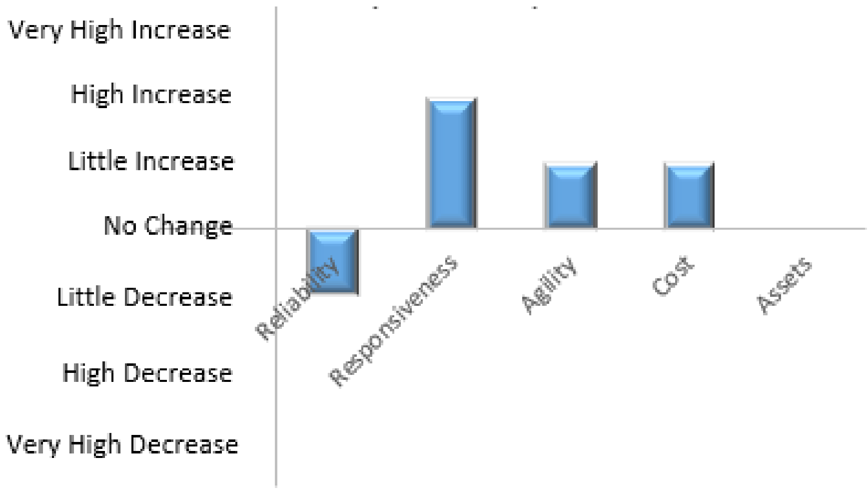


Figure 6.4 Performance measurement considerations by attribute during COVID-19 pandemic

Performance consideration regarding the responsiveness attribute had a high increase in emphasis. The attributes agility, cost related performance considerations have also increased a little. On the other hand, reliability related performance consideration shows a slight decrease, and no change was recognised in the assets management efficiency attribute.

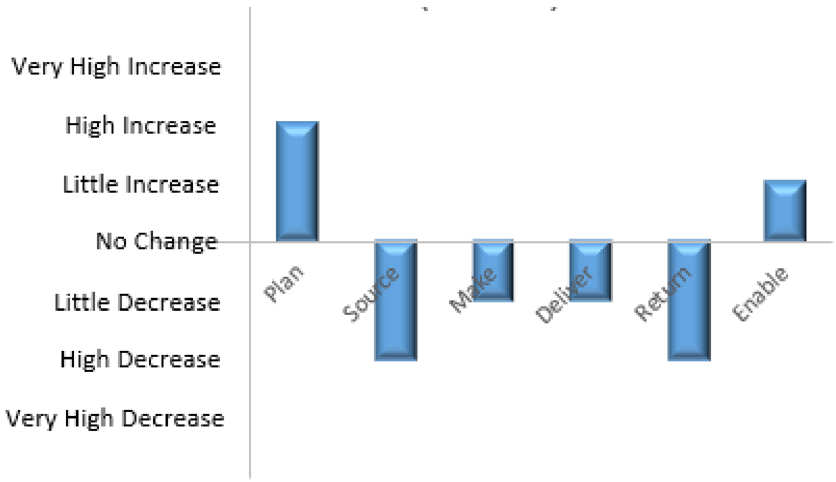


Figure 6.5 Performance measurement considerations by process during COVID-19 pandemic

Figure 6.5 above shows how much the process-related performance considerations have changed during the COVID-19 disruption, as perceived by the focus group participants. According to Figure 6.5, the airline catering organisation appears to give considerations towards placing more emphasis on plan and enable processes during the pandemic. Performance considerations for the make and deliver processes have decreased a little in emphasis, whilst the source and return processes have highly decreased in emphasis.

Figure 6.6 below illustrates the perception of the focus group participants on the relative weights of performance attributes in each of the MoSCoW priority groups. The weight of a performance attribute in a priority group is derived from the number of corresponding performance metrics of the attributes within the priority group.

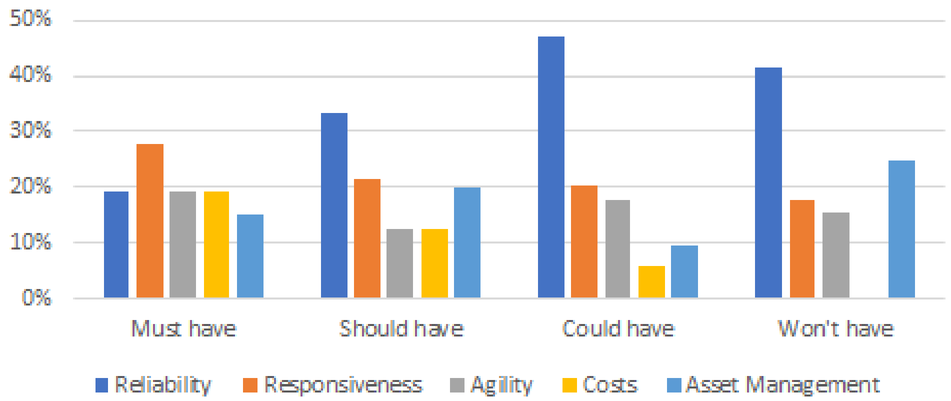


Figure 6.6 Analysis of prioritised metrics by performance attribute

Figure 6.7 below shows the perception of the focus group participants on the relative weights of supply chain processes in each of the MoSCoW priority groups. The weight of a process in a priority group is derived from the number of corresponding performance metrics of the processes within the priority group.

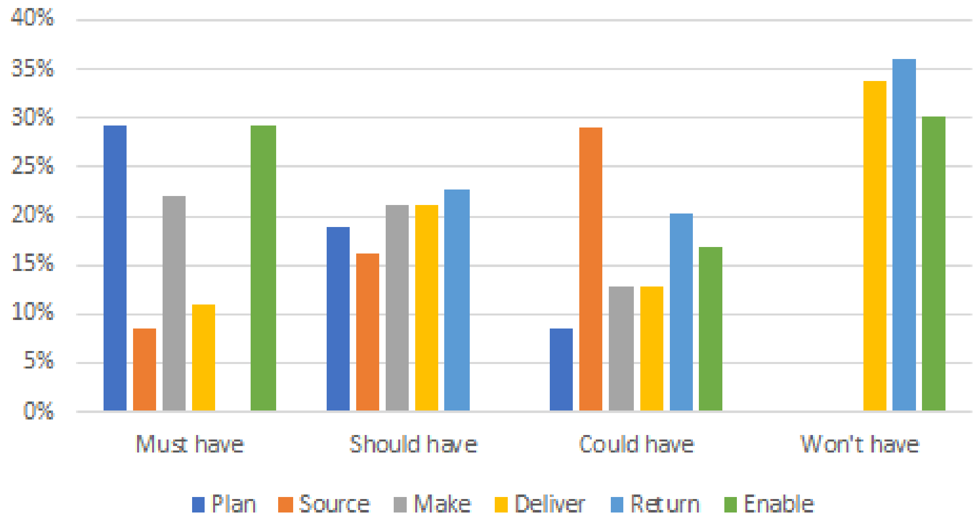


Figure 6.7 Analysis of prioritised metrics by process

6.5 Discussion

The MoSCoW prioritisation results in Figure 6.3 align with the experience of focus group participants regarding the COVID-19 pandemic in the airline catering supply chain. Performance metrics capture the effectiveness of the supply chain to the effect of uncertainties presented by the COVID-19 pandemic appeared to have been recognised in the prioritisation. For example, 'external event response time' metric related to responsiveness attribute and enable process, cost-related metrics such as mitigation cost and direct labour cost, and upside, downside adaptability which are associated with agility attribute and make process. The least prioritised includes the percentage of item location accuracy due to the simplified catering procedure and the temporary alterations in packing plans, receive excess product cycle time, and capacity utilisation.

In Figure 6.6, the responsiveness attribute has the highest priority in the Must-have group whilst the reliability attribute has the highest priority in the should-have, could-have, and won't-have groups. Reliability is generally considered crucially important (Jones, 2012a), and it has the highest number of metrics in the developed airline catering performance metrics set. Hence, it has the highest rating in all the groups except Must-have, which is not surprising. Responsiveness came out top in the Must-have group primarily due to the significant uncertainties presented by the COVID-19 pandemic. An organisation needs to understand the uncertainties in its supply chain and supply chain responsiveness to achieve and sustain strategic alignment (Sundarakani *et al.*, 2018). Time is critical in the airline catering logistics process (Jones, 2012b), more so under high uncertainties, and it's important to respond to any catering related queries as quickly as possible. Catering issue resolution time must be quicker during an emergency period. There is an expectation for stricter adherence to the specific time slot allocated to each airline by airport management for flight operations during the COVID-19 pandemic; hence, the catering service provider needs to be more responsive in managing the decatering and catering operations. The participants expressed a view that airlines appear to be more tolerant of the inflight meal and refreshments services during the COVID-19 pandemic period, hence the probable emergence of responsiveness attribute over reliability attribute in the Must-have group. The participants felt that during the COVID-19 pandemic, airlines are placing more emphasis on several other issues, including passengers' health and safety (Dube *et al.*, 2021), in contrast to routine inflight meals and refreshments operations, although food safety remains appropriately prioritised (Jones, 2007). Interestingly the cost performance attribute does not appear in the won't-have group as each of its metrics is at least a could have.

There is a perception of an increase in performance measurement considerations for responsiveness, agility, and cost performance attribute, with the highest increase expressed for the responsiveness attribute (see, Figure 6.4). The agility performance attribute helps to measure the ability of airline catering service providers to manage airline disruptions (APICS, 2017). Disruptive events such as the COVID-19 pandemic give rise to the incidence of flight cancellations and sometimes airport closures, affecting airlines and passengers (Jones, 2012a). The airline catering organisation should be flexible to provide enough refreshments for affected passengers at the airport and may be required to fulfil large supplementary order quantities for the next available service flight as a high number of passengers may be transferred from cancelled flights. Several airlines stopped their onboard meal service or diminished catering service extremely during COVID-19 (Amankwah-Amoah, 2020). Whilst the reduction in inflight service during the pandemic could be a safety measure, it can be argued that the meal service cuts by some airlines were fully or partly motivated by a cost-saving strategy. Therefore, there is an increased need for caterers to put additional measures to control catering operation costs and provide cost-effective inflight service. According to the focus group feedback, asset management attribute remains unchanged during the COVID-19 pandemic compared to other attributes as inventory of products and equipment has no implication on service stability in the relatively quiet catering operations. The organisation is also seeing very low capacity utilisation during the COVID-19 pandemic.

In Figure 6.7, both plan and enable processes have the greater preferences in the Must-have group, while the make process has the next higher preference. Plan process is highly regarded due to the uncertainty in airline operations during the COVID-19 outbreak; thus airline catering supply chain need to plan and respond quickly according to the airline catering requirements (Sundarakani *et al.*, 2018). Participants perceive that the performance consideration associated with determining airline catering requirements and corrective actions to achieve catering service objectives becomes increasingly important during the COVID-19 pandemic than ever before. As the outbreak and uncertainties continue to dominate, many changes and restrictions are being introduced in arrival destinations day by day. Therefore, catering service providers also need to plan and react fast in delivering service according to the airline's decisions.

The focus group participants perceive that the enable process-related metrics as highly important for mitigating airline catering supply chain disruption during the COVID-19 pandemic. Many regulations, guidance, and safety precautions relating to COVID-19 are being updated frequently (Belhadi *et al.*, 2021). This affects flight operations and schedules and causes flight cancellations and delays. Caterers need to come up with a mitigation plan for inflight catering services within a short timeframe (Lin, 2018). The focus group participants noted that the criticality of the enable process is more pronounced during the COVID-19 pandemic as it provides essential inputs and directions to support the planning and execution procedures of the airline catering supply chain during COVID-19 by maintaining and monitoring information, airline instruction, and compliance. Normally, due to the changes in aircraft and schedules, re-catering as per the service level changes and re-assembly work of catering containers becomes inevitable in airline catering operations (Law, 2011). Attention to the changes and their consequences is more evident during the COVID-19 pandemic; hence, participants also prioritised some metrics relevant to make process.

As shown in Figure 6.5, there is an increase in performance measurement considerations for plan and enable processes and a decrease in source, make, deliver and return process related performance considerations, with the highest drop considered for source and return processes during the COVID-19 pandemic. Due to lower demand for airline catering orders, Company X's purchasing activities have dropped significantly. It is not surprising that the relevance of source process related performance measures has been highly decreased. The in-flight meal offering is needed to be altered to have more simplified procedures and menus to comply with temporary health and safety restrictions and social distancing rules (Pongpirul *et al.*, 2020). Pre-packaged meals are provided in disposable containers for some medium or high-risk routes. Passengers can use the same containers to store catering waste afterwards. Therefore, less catering wastage and catering equipment needed to be collected from return flights by the catering service provider and return sortation, recouping, and recycling activities happen in the service centre on a much smaller scale compared to pre COVID-19 pandemic. This leads to a high decrease in the return process related performance consideration during COVID-19. Although there is a perception of a significant impact on make and deliver processes due to low volumes, the relevance of these process related performance measures has only slightly decreased. Company X experiences the inevitable catering service amendments due to flight schedule changes or aircraft type changes. Such amendments can be quite frequent in uncertain times, and catering service providers should be flexible in completing any catering requirements changes within a given time (Hovora, 2001). Catering service providers may sometimes need to provide a different menu for all the passengers or completely reassemble and repack for different aircraft equipment types.

The participants in this case study mainly focused on operational efficiency in the development of the performance metrics for the airline catering supply chain. During the focus group discussion, the participants deliberated on challenges arising from the COVID-19 pandemic in the context of the airline catering supply chain. The challenges include those associated with food hygiene, safety measures (Dube *et al.*, 2021), training issues, low passengers and flight operations, loss of revenue (Rimmer, 2020), greater uncertainties, frequent service requirements changes and inventory management chaos (Gunessee and Subramanian, 2020), sustainability issues and performance measurement difficulties. Due to these challenges, airline catering will need to adapt performance management in line with COVID-19 measures. The participants believe that the performance metrics listed in Table 6.4 would help address some of the challenges attributed to the COVID-19 pandemic. They opined that the metrics prioritisation would guide the management regarding the focus areas during challenging times in the COVID-19 pandemic. There are several lessons learnt from the COVID-19 pandemic. There is a shift in performance metrics parameters; the entire airline catering industry has taken suitable measures to meet new requirements & challenges posed by COVID-19. Without performance metrics, catering service providers will not be able to meet the supply and demand needs of the airlines as and when circumstances change. Flexibility is a key principle required at the moment to maintain relationships and enhance trust in the airline catering supply chain. Supply chain organisations must possess collaborative resilience to recover from severe disruptions like the COVID-19 pandemic (Ramanathan *et al.*, 2021). Hence, airlines should also view their caterers and logistics service providers as part of their bubble and provide the support and care they require.

6.6 Chapter Summary

This chapter presents the SCOR model for examining and mapping the airline catering supply chain processes because of its easily adaptable and customisable features. The SCOR model was extended to be more suitable for the airline catering environment by linking SCOR performance attributes with airline catering logistics performance. This chapter includes the performance metrics developed for the airline catering supply chain related to each of the five performance attributes recognised in the SCOR model. Then, it discusses the adaptation of SCOR-based performance metrics during COVID-19 using the airline catering supply chain as a case study. MoSCoW prioritisation technique has been used to classify the choice of performance metrics according to the performance measure considerations during emergencies. The findings show that the airline catering supply chain needs to adapt its performance metrics, particularly those associated with responsiveness and reliability performance attributes. Less so are the performance metrics related to asset management efficiency.

7 Practice Effectiveness

7.1 Introduction

Many organisations have realised significant benefits after implementing best supply chain practices, and there are important lessons to be learnt across industry sectors, including in the airline catering industry. The airline catering industry is facing intense pressure to improve its service performance. An appropriate evaluation of supply chain practices will help in implementing effective practices to strengthen the competitive position. Methods for evaluating supply chain practice effectiveness regarding the importance and performance characteristics of the practices are needed.

In the airline catering supply chain literature, research studies investigate, for example, the strategies that strengthen the organisation's competitive position (Sundarakani *et al.*, 2018), analyse supply chain processes and logistics service performance (Rajaratnam and Sunmola, 2020a), and explore how performance metrics can be adapted in uncertain times (Rajaratnam and Sunmola, 2021b). There is a dearth of evaluation methods for measuring how airline catering supply chain practices are performing and which practices have a high-level contribution toward overall supply chain practice effectiveness. The research reported in this chapter contributes to the airline catering supply chain literature by developing a method for evaluating airline catering supply chain practice effectiveness. Development of practice effectiveness assessments is necessary to enhance the airline catering logistics service efficiency, employee experience, and customer satisfaction, especially when the assessment method offers a decision-making procedure for dealing with practice choices and rankings. The research project described in this chapter addresses the following research questions.

1. What approach can be used to evaluate supply chain practice effectiveness in the airline catering supply chain?
2. How can the approach be applied to identify the areas of airline catering supply chain practices that need to improve?

To answer the two research questions above, this research adopts a fuzzy logic approach in the context of the supply chain operations reference (SCOR) framework (APICS, 2017) and demonstrates its application using a case study. The effectiveness evaluation method developed in this chapter computes an index of fuzzy overall practice effectiveness (FOPE) for airline catering supply chains that helps airline catering organisations in determining their practice effectiveness level. This study also introduces an index for measuring the performance importance of a supply chain practice called the fuzzy performance importance index (FPII) of airline catering supply chain practices. The ranking of practices using the FPII helps management identify weaker practices, for continuous improvement actions.

The remainder of this chapter is structured as follows. The next Section 7.2 presents the research methodology and the design of the conceptual model. Section 7.3 elaborates on the case study details and demonstrates the evaluation steps of the practice effectiveness assessment. Section 7.4 discusses the case study results and explains the implication. The last Section 7.5 concludes the chapter summary.

7.2 Conceptual Model for Practice Effectiveness Assessment

7.2.1 Methodology

A literature review on related work has been carried out as described in Chapter 3. Following the review, a conceptual model for evaluating supply chain practice effectiveness is then developed and described in subsection 7.2.2. The methodology used in this study is shown in Figure 7.1. The conceptual model has been developed primarily based on the SCOR framework at three levels: performance attribute, practice category, and supply chain practices (APICS, 2017). Performance attributes represent the strategic characteristics of supply chain effectiveness. The other two levels of the conceptual model, practice category and supply chain practices, represent primary and secondary level effectiveness factors. SCOR model recognises several supply chain practices that exist within organisations. These practices have been classified into practice categories based on information from experts in various industry sectors.

Based on the conceptual model, a practice effectiveness evaluation method (PEEM) is developed in this chapter and described using an airline catering organisation as a case study. An expert team of five members was formed into a focus group. The five experts are senior managers in various departments in the case study organisation. The experts were requested to provide data on performance rating and the importance weights of practice effectiveness (PE) factors in the context of airline catering organisation's supply chain using linguistic variables. The five experts deliberated and reached a consensus on the data they provided. The data provided by experts were in linguistics terms, and they are converted into appropriate fuzzy numbers which are used to calculate the FOPE of airline catering supply chain organisation. The data provided by the experts are also used as input for identifying weaker practices and proposals for improvement.

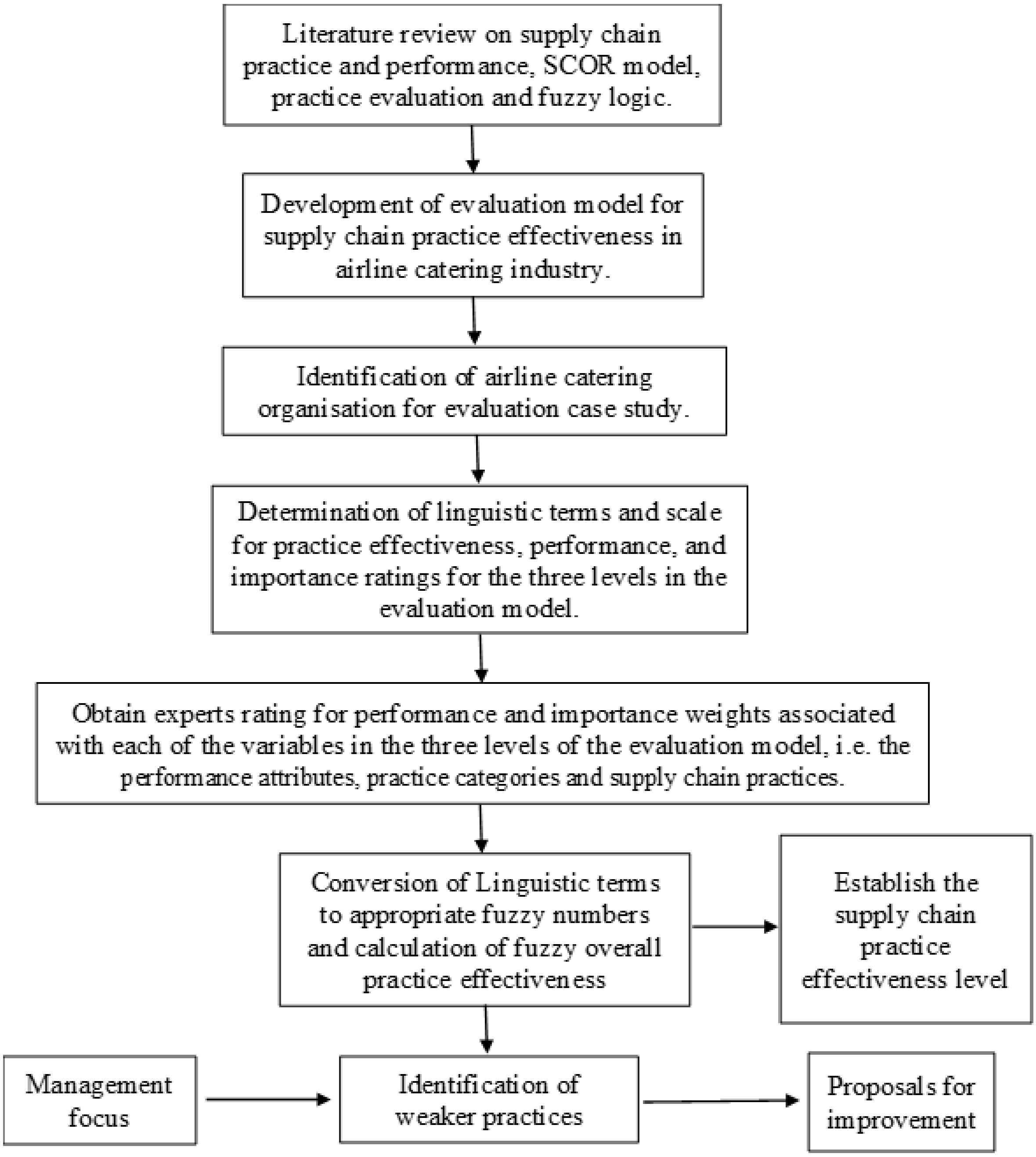


Figure 7.1 Methodology

7.2.2 Design of the conceptual model

The conceptual model for the supply chain practice effectiveness evaluation is developed and shown in Table 7.1. The model consists of three levels, primarily adopted from the SCOR framework. In the context of the airline catering supply chain reported in this research, the first level consists of five performance attributes, the second level consists of 13 practice categories, and the third level comprises 39 supply chain practices. These practices have been proven in a diverse range of business environments and industries (Georgise *et al.*, 2013). A different set of practice categories will lead to different performance expectations.

Table 7.1 Conceptual model for supply chain practice effectiveness assessment in Airline Catering Supply Chain. Motivated from SCOR Model Version 12 (APICS, 2017)

Performance attribute	Practice category	Supply chain practice
Reliability (PE_1)	Information Management (PE_{11})	Master Data Accuracy (PE_{111})
		Electronic Data Interchange-EDI (PE_{112})
		Barcoding/RFID (PE_{113})
	Order Management (PE_{12})	Pick List Generation (PE_{121})
		Bill of Material Audit/Control (PE_{122})
		Generation of Dynamic Bills of Materials (PE_{123})
	Reverse Logistics (PE_{13})	Return Tracking (PE_{131})
		Return Load Optimisation (PE_{132})
		Automated Identification/Disposition of Over Shipments (PE_{133})
Responsiveness (PE_2)	Planning and Forecasting (PE_{21})	Sales and Operations Planning (PE_{211})
		Safety Stock Planning (PE_{212})
		Scenario Planning (PE_{213})
	Production (PE_{22})	Production Line Sequencing (PE_{221})
		Production Scheduling Optimisation (PE_{222})
		Batch Size Reduction (PE_{223})
	Transportation Management (PE_{23})	Cross-Docking (PE_{231})
		Transportation Management System (PE_{232})
		Logistics & Warehouse Planning (PE_{233})
Agility (PE_3)	Risk Management (PE_{31})	Supply Chain Risk Monitoring (PE_{311})
		Supply Chain Risk Assessment (PE_{312})
		Supply Chain Risk Management (PE_{313})
	Purchasing (PE_{32})	Maintain Supply Chain Risk Register (PE_{321})
		Supplier Research (PE_{322})
		Strategic Sourcing (PE_{323})
Cost (PE_4)	Performance Management (PE_{41})	Standard Operating Procedures (PE_{411})
		Performance targets (PE_{412})
		Employee performance monitoring (PE_{413})
	Continuous Improvement (PE_{42})	Gemba Walks (PE_{421})
		DMAIC practice (PE_{422})
		Team-based Problem Solving (PE_{423})
	People Management (PE_{43})	Cross-Functional Teams (PE_{431})

		Employee Training (PE_{432})
		Employee Recognition & Reward (PE_{433})
Asset Management Efficiency (PE_5)	Inventory Management (PE_{51})	Consignment Inventory Management (PE_{511})
		Baseline Inventory Monitoring (PE_{512})
		ABC Inventory Classification (PE_{513})
	Business Process Analysis (PE_{52})	Automated Data Capture-ADC (PE_{521})
		Business Rule Management (PE_{522})
		Lean (PE_{523})

The conceptual model reflects the association between the supply chain practices, practice categories, and performance attributes based on the SCOR model. The five performance attributes in the model are defined in Table 7.2. These performance attributes have also been used in previous studies, for example (Kusrini *et al.*, 2019).

Table 7.2 SCOR Performance Attributes (APICS, 2017)

Performance Attribute	Description
Reliability	The reliability attribute addresses the ability to perform tasks as expected. Reliability focuses on the predictability of the outcome of a process.
Responsiveness	The responsiveness attribute describes the speed at which tasks are performed. Responsiveness addresses the repeated speed of doing business.
Agility	The agility attribute describes the ability to respond to external influences; the capability and speed of change.
Costs	The cost attribute describes the cost of operating the supply chain process. Typical costs include labour, materials, systems, and transportation costs.
Asset Management Efficiency	The asset management efficiency (“Assets”) attribute describes the ability to efficiently utilise assets. Asset management strategies in a supply chain include inventory reduction and in-sourcing vs outsourcing.

The supply chain PEEM covers various perspectives of effectiveness assessment. As an example, consider the reliability performance attribute in Table 7.1. The case study airline catering organisation recognises three practice categories as the major focus areas of reliability which are information management, order management, and reverse logistics. The practice categories considered in this evaluation are defined in Table 7.3 below.

Table 7.3 Practice Categories

Practice Category / Function	Description
Information Management	The collection and management of information from one or more sources and the distribution of that information to one or more audiences.
Order Management	The process of efficiently tracking and fulfilling sales orders.
Reverse Logistics	The series of activities required to retrieve a used product from a customer and either dispose of it or reuse it.
Planning and Forecasting	The process of anticipating the demand for products and planning their materials.
Production	The activity of producing finished products in the form of goods and services.
Transportation Management	The management of planning, executing, and optimising the physical movement of incoming and outgoing goods.
Risk Management	The process of identifying, assessing and controlling the risk in an organisation's end-to-end supply chain.
Purchasing	The process of buying the goods and services that a company needs to accomplish its goal.
Performance Management	The process of monitoring, maintaining and improving employee performance in line with an organisation's objectives.
Continuous Improvement	An organised approach to constantly re-examining processes and identifying opportunities for improvement.
People Management	The task of organising employees and teams to optimise performance.
Inventory Management	The process of ordering, handling, storing, and using a company's raw materials and finished goods.
Business Process Analysis	The analysis of a business to understand its process and improve its efficiency.

The supply chain practices associated with the information management practice category are master data accuracy, electronic data interchange, and Barcoding/RFID. The supply chain practices associated with the order management practice category are picklist generation, bill of material audit, and generation of dynamic bill of materials. The supply chain practices associated with the reverse logistics practice category are return tracking, return load optimisation, and automated identification and disposition of over shipments. The practices relevant to the airline catering supply chain of the case study organisation are listed in Table 7.4 below.

Table 7.4 Supply Chain Practices

Supply Chain Practice	Description
Master Data Accuracy	Re-validate existing Master Data (order lead times, replenishment times, transit times, etc.) to ensure it matches current operational capabilities and performance.
Electronic Data Interchange (EDI)	The practice of exchanging workflow related documents - such as forecasts, purchase orders, order confirmations, work orders, inventory adjustments, and invoices - via electronic standard messages.
Bar coding/RFID	Bar coding is the practice of adding machine readable labels to packaging of goods, in order to increase reading speed and reduce reading errors.
Pick List Generation	A Pick List is a sequential list of all components and materials required to fill a specific production, sales or interplant order.
Bill of Material Audit/Control	Auditing and controlling the accuracy of the bills of material through routine reviews. It includes ensuring the correct part quantities, verifying parts, and ensuring correct subassemblies transform into final product.
Generation of Dynamic Bills of Materials	Ability to produce different mixes or a variety of products quickly using IT application based on customer order requirements and specification, product and customer rules.
Return Tracking	The process of tracking return shipment details when excess or unused products are returned.
Return Load Optimisation	The practice of combining customer deliveries with customer pick-ups for returns
Automated Identification/Disposition of Over Shipments	Verification and identification of over shipped product at time of receiving using automated supply chain management systems.
Sales and Operations Planning	Mid to Long Term supply chain planning practice which seeks to compare the forecast sales plan to the company resources, (production capacity, people, raw materials) and analyze where any imbalances to the plan might exist.
Safety Stock Planning	Planning a minimum inventory level in order to protect from stock-outs.
Scenario Planning	Scenario Planning, also called What-If Analysis, is a process and analytical capability that enables real-time event driven decision making.
Production Line Sequencing	The practice where materials are ordered, shipped, received and/or staged in the same sequence as they will be consumed.
Production Scheduling Optimisation	Optimising production scheduling using technology such as ERP system to maximize the throughput on a given asset while optimising the other related processes.

Batch Size Reduction	Use Lean principles to reduce size of manufacturing batch sizes to better match customer demand vs. asset utilization/quality issues.
Cross-Docking	Cross docking is the practice of unloading materials from an incoming vehicle and loading these materials directly onto outbound vehicles without putting away into the regular storage locations in a warehouse.
Transportation Management System	IT applications are used by major corporations to optimise plans and manage inbound and outbound logistics.
Logistics & Warehouse Planning	The practice of considering the distribution locations, transport paperwork requirements, duties/taxes, and warehouse strategy at the point of planning.
Supply Chain Risk Monitoring	The practice of establishing a formal process to continuously monitor the changes in probability or impact of risk events.
Supply Chain Risk Assessment	Supply Chain Risk assessment provides management with an understanding of where the greatest risks may exist in order to prioritize resources for risk mitigation and management.
Supply Chain Risk Management	Supply chain risk management is the systematic identification, assessment and mitigation of potential disruptions in logistics networks with the objective to reduce their negative impact on the logistics network's performance.
Maintain Supply Chain Risk Register	A risk register captures all the risk exposure for a supply chain, once the risks are identified and assessed in terms of probability of occurrence and impact.
Supplier Research	The practice of identifying suitable suppliers who are able to meet the planned requirements.
Strategic Sourcing	Strategic sourcing is an institutional procurement process that continuously improves and re-evaluates the purchasing activities of a company.
Standard Operating Procedures	An SOP is a written document or instruction detailing all steps and activities of a process or procedure. An SOP provides employees with a reference to common business practices, activities, or tasks.
Performance targets	Setting employee performance goals and objectives
Employee performance monitoring	Regular monitoring and tracking the Performance of an Employee
Gemba Walks	Walking around a shop floor where operations take place in order to reduce Waste and improve processes.
DMAIC practice	It is data driven approach for improving business processes through 5 steps-Define, Measure, Analyze, Improve and Control

Team-based Problem Solving	Using teams that has the knowledge, time, authority and skill to solve the problem and implement corrective actions.
Cross Functional Teams	A cross-functional team is a group of people with different functional expertise working toward a common goal.
Employee Training	Providing employees the specific knowledge or skills to improve performance in their current roles
Employee Recognition & Reward	The acknowledgment of an organisation's employees for best performance and high quality work and rewarding them for their efforts.
Consignment Inventory Management	The practice of making inventory available at the customer premises, while the vendor carries the cost of ownership and liability of these materials or goods.
Baseline Inventory Monitoring	Regular review of baseline inventory levels to avoid overstock situations. Baseline inventory is defined as the lowest stock level that a particular SKU actually had during the last 12 months.
ABC Inventory Classification	An approach for classifying inventory items based on the items' consumption values.
Automated Data Capture (ADC)	Process of automatically capturing data relate to movement of items in the warehouse in real time
Business Rule Management	Business Rules Management is the practice where business rules are in a (human-readable) form that are used by, but not embedded in, supply chain systems.
Lean	'Lean' is a production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful and thus a target for elimination.

7.3 Case Study

The case study details are described in this section and are used to illustrate the supply chain PEEM calculations. The case study was conducted in an airline catering organisation based in the U.K. As mentioned in the introduction chapter, the case study organisation is referred to as Company X in this research. Company X is keen to improve its supply chain practice effectiveness and airline catering logistics service performance.

The calculation of fuzzy overall practice effectiveness is done in four steps detailed in Sections 7.3.1, 7.3.2, 7.3.3 and 7.3.4. In the calculations, triangular fuzzy numbers for linguistics variables regarding importance weights and performance ratings are shown in Table 7.5.

Table 7.5 Triangular fuzzy numbers for linguistics variables

Importance weight	
Linguistic variable	**Fuzzy number**
Very Low (VL)	(0, 0.05, 0.15)
Low (L)	(0.1, 0.2, 0.3)
Fairly Low (FL)	(0.2, 0.35, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
Fairly High (FH)	(0.5, 0.65, 0.8)
High (H)	(0.7, 0.8, 0.9)
Very High (VH)	(0.85, 0.95, 1)

Performance rating	
Linguistic variable	**Fuzzy number**
Worst (W)	(0, 0.5, 1.5)
Very Poor (VP)	(1, 2, 3)
Poor (P)	(2, 3.5, 5)
Fair (F)	(3, 5, 7)
Good (G)	(5, 6.5, 8)
Very Good (VG)	(7, 8, 9)
Excellent (E)	(8.5, 9.5, 10)

The nomenclature of the practice effectiveness evaluation model is described Table 7.6 below.

Table 7.6 Nomenclature

$FOPE$	= Performance index for fuzzy overall practice effectiveness.
W_i	= Importance weight of i^{th} performance attribute.
PE_i	= Practice effectiveness factor of i^{th} performance attribute.
W_{ij}	= Importance weight of j^{th} practice category in i^{th} performance attribute.
PE_{ij}	= Practice effectiveness factor of j^{th} practice category in i^{th} performance attribute.
W_{ijk}	= Importance weight of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.
R_{ijk}	= Performance rating of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.
$OPEL$	= Overall practice effectiveness level.
$D(FOPE, OPEL)$	= Euclidean distance between FOPE and $OPEL$.
$FPII_{ijk}$	= Fuzzy performance importance index for k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.

The importance weight and performance ratings of practice effectiveness factors are evaluated by choosing these linguistic variables. The five experts from Company X gave their consensus linguistics values for importance weights and performance ratings, and the data is shown in Table 7.7.

Table 7.7 Performance ratings and importance weights provided by experts in the case study company

Performance attribute	W_i	Practice category	W_{ij}	Supply chain practice	W_{ijk}	R_{ijk}
Reliability	FH	Information Management	FH	Master Data Accuracy	H	VG
				Electronic Data Interchange-EDI	FH	G
				Barcoding/RFID	FH	F
		Order Management	H	Pick List Generation	H	VG
				Bill of Material Audit/Control	FH	F
				Generation of Dynamic Bills of Materials	M	VG
		Reverse Logistics	M	Return Tracking	FH	VG
				Return Load Optimisation	M	G
				Automated Identification/Disposition of Over Shipments	M	F
Responsiveness	H	Planning and Forecasting	H	Sales and Operations Planning	H	G
				Safety Stock Planning	FH	G
				Scenario Planning	FH	F
		Production	M	Production Line Sequencing	M	F
				Production Scheduling Optimisation	H	G
				Batch Size Reduction	M	G
		Transportation Management	H	Cross-Docking	M	F
				Transportation Management System	H	VG
				Logistics & Warehouse Planning	H	VG
Agility	M	Risk Management	M	Supply Chain Risk Monitoring	M	F
				Supply Chain Risk Assessment	M	G
				Supply Chain Risk Management	FH	G
		Purchasing	FH	Maintain Supply Chain Risk Register	FL	P
				Supplier Research	M	G
				Strategic Sourcing	FH	F

(*continued*)

Performance attribute	W_i	Practice category	W_{ij}	Supply chain practice	W_{ijk}	R_{ijk}
Cost	H	Performance Management	FH	Standard Operating Procedures	H	VG
				Performance targets	FH	G
		Continuous Improvement	H	Employee performance monitoring	FH	G
				Gemba Walks	H	G
				DMAIC practice	FH	F
		People Management	FH	Team-based Problem Solving	FH	G
				Cross-Functional Teams	M	F
				Employee Training	H	G
				Employee Recognition & Reward	FH	G
Asset Management Efficiency	M	Inventory Management	FH	Consignment Inventory Management	M	F
				Baseline Inventory Monitoring	H	G
				ABC Inventory Classification	M	F
		Business Process Analysis	M	Automated Data Capture-ADC	M	G
				Business Rule Management	FL	G
				Lean	H	G

7.3.1 Primary evaluation measurement

In primary evaluation measurement, the practice effectiveness factor of j^{th} practice category in i^{th} performance attribute is calculated using Equation (7.1) as per the fuzzy weighted average definition:

$$\mathbf{PE}_{ij} = \frac{\sum_k \boldsymbol{W_{ijk}} \otimes \boldsymbol{R_{ijk}}}{\sum_k \boldsymbol{W_{ijk}}} \tag{7.1}$$

PE_{ij} = Practice effectiveness factor of j^{th} practice category in i^{th} performance attribute.
R_{ijk} = Performance rating of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.
W_{ijk} = Importance weight of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.

To illustrate, the calculation is applied to the first practice category, 'Information Management', relating to the first attribute, 'Reliability', as follows.

$$\mathrm{PE}_{11} = \frac{\{[(0.7, 0.8, 0.9) \otimes (7, 8, 9)] \oplus [(0.5, 0.65, 0.8) \otimes (5, 6.5, 8)] \oplus [(0.5, 0.65, 0.8) \otimes (3, 5, 7)]\}}{[(0.7, 0.8, 0.9) \oplus (0.5, 0.65, 0.8) \oplus (0.5, 0.65, 0.8)]}$$

$$= (5.24, 6.61, 8.04)$$

Similarly, the practice effectiveness factors for other practice categories in their corresponding attributes are calculated and presented in Table 7.8.

7.3.2 Secondary evaluation measurement

In secondary evaluation measurement, the practice effectiveness factor of i^{th} performance attribute is calculated using Equation (7.2).

$$\mathrm{PE}_i = \frac{\sum_j \; W_{ij} \otimes PE_{ij}}{\sum_j \; W_{ij}} \tag{7.2}$$

PE_i = Practice effectiveness factor of i^{th} performance attribute.
W_{ij} = Importance weight of j^{th} practice category in i^{th} performance attribute.
PE_{ij} = Practice effectiveness factor of j^{th} practice category in i^{th} performance attribute.

To illustrate, the practice effectiveness index of the first performance attribute, 'Reliability' is calculated as follows.

$$\mathrm{PE}_1 = \frac{\left\{\begin{matrix}[(0.5, 0.65, 0.8) \otimes (5.24, 6.61, 8.04)] \oplus \\ [(0.7, 0.8, 0.9) \otimes (5.67, 7, 8.33)] \oplus \\ [(0.3, 0.5, 0.7) \otimes (5.36, 6.64, 8.05)]\end{matrix}\right\}}{[(0.5, 0.65, 0.8) \oplus (0.7, 0.8, 0.9) \oplus (0.3, 0.5, 0.7)]}$$

$$= (5.46, 6.78, 8.15)$$

Similarly, the practice effectiveness indices for other performance attributes are calculated and are presented in Table 7.8.

7.3.3 Tertiary evaluation measurement

In tertiary evaluation measurement, Fuzzy overall practice effectiveness (FOPE) index is computed using Equation (7.3). The FOPE index represents the overall supply chain fuzzy practice effectiveness level, and in this project that of an airline catering organisation.

$$\boldsymbol{FOPE} = \frac{\sum_i \boldsymbol{W_i} \otimes \boldsymbol{PE_i}}{\sum_i \boldsymbol{W_i}} \qquad \textbf{(7.3)}$$

FOPE = Fuzzy overall practice effectiveness index.
W_i = Importance weight of i^{th} performance attribute.
PE_i = Practice effectiveness factor of i^{th} performance attribute.

FOPE index for the case study airline catering supply chain is calculated using Equation (7.3) and the values in Table 7.8, as follows.

$$\mathrm{FOPE} = \frac{\left\{\begin{matrix}[(0.5, 0.65, 0.8) \otimes (5.46, 6.78, 8.15)] \oplus [(0.7, 0.8, 0.9) \otimes (5.21, 6.52, 7.96)] \oplus \\ [(0.3, 0.5, 0.7) \otimes (3.8, 5.54, 7.24)] \oplus \\ [(0.7, 0.8, 0.9) \otimes (4.88, 6.38, 7.91)] \oplus [(0.3, 0.5, 0.7) \otimes (4.42, 6.03, 7.68)]\end{matrix}\right\}}{[(0.5, 0.65, 0.8) \oplus (0.7, 0.8, 0.9) \oplus (0.3, 0.5, 0.7) \oplus (0.7, 0.8, 0.9) \oplus (0.3, 0.5, 0.7)]}$$

$$= (4.9, 6.31, 7.81)$$

Table 7.8 Fuzzy number approximation for linguistic variables

PE_i	W_i	PE_{ij}	W_{ij}	W_{ijk}	R_{ijk}
$PE_1 = (5.46, 6.78, 8.15)$	$W_1 = (0.5, 0.65, 0.8)$	$PE_{11} = (5.24, 6.61, 8.04)$	$W_{11} = (0.5, 0.65, 0.8)$	$W_{111} = (0.7, 0.8, 0.9)$	$R_{111} = (7, 8, 9)$
				$W_{112} = (0.5, 0.65, 0.8)$	$R_{112} = (5, 6.5, 8)$
				$W_{113} = (0.5, 0.65, 0.8)$	$R_{113} = (3, 5, 7)$
		$PE_{12} = (5.67, 7, 8.33)$	$W_{12} = (0.7, 0.8, 0.9)$	$W_{121} = (0.7, 0.8, 0.9)$	$R_{121} = (7, 8, 9)$
				$W_{122} = (0.5, 0.65, 0.8)$	$R_{122} = (3, 5, 7)$
				$W_{123} = (0.3, 0.5, 0.7)$	$R_{123} = (7, 8, 9)$
		$PE_{13} = (5.36, 6.64, 8.05)$	$W_{13} = (0.3, 0.5, 0.7)$	$W_{131} = (0.5, 0.65, 0.8)$	$R_{131} = (7, 8, 9)$
				$W_{132} = (0.3, 0.5, 0.7)$	$R_{132} = (5, 6.5, 8)$
				$W_{133} = (0.3, 0.5, 0.7)$	$R_{133} = (3, 5, 7)$
$PE_2 = (5.21, 6.52, 7.96)$	$W_2 = (0.7, 0.8, 0.9)$	$PE_{21} = (4.41, 6.04, 7.68)$	$W_{21} = (0.7, 0.8, 0.9)$	$W_{211} = (0.7, 0.8, 0.9)$	$R_{211} = (5, 6.5, 8)$
				$W_{212} = (0.5, 0.65, 0.8)$	$R_{212} = (5, 6.5, 8)$
				$W_{213} = (0.5, 0.65, 0.8)$	$R_{213} = (3, 5, 7)$
		$PE_{22} = (4.54, 6.08, 7.7)$	$W_{22} = (0.3, 0.5, 0.7)$	$W_{221} = (0.3, 0.5, 0.7)$	$R_{221} = (3, 5, 7)$
				$W_{222} = (0.7, 0.8, 0.9)$	$R_{222} = (5, 6.5, 8)$
				$W_{223} = (0.3, 0.5, 0.7)$	$R_{223} = (5, 6.5, 8)$
		$PE_{23} = (6.29, 7.29, 8.44)$	$W_{23} = (0.7, 0.8, 0.9)$	$W_{231} = (0.3, 0.5, 0.7)$	$R_{231} = (3, 5, 7)$
				$W_{232} = (0.7, 0.8, 0.9)$	$R_{232} = (7, 8, 9)$
				$W_{233} = (0.7, 0.8, 0.9)$	$R_{233} = (7, 8, 9)$
$PE_3 = (3.8, 5.54, 7.24)$	$W_3 = (0.3, 0.5, 0.7)$	$PE_{31} = (4.45, 6.05, 7.68)$	$W_{31} = (0.3, 0.5, 0.7)$	$W_{311} = (0.3, 0.5, 0.7)$	$R_{311} = (3, 5, 7)$
				$W_{312} = (0.3, 0.5, 0.7)$	$R_{312} = (5, 6.5, 8)$
				$W_{313} = (0.5, 0.65, 0.8)$	$R_{313} = (5, 6.5, 8)$
		$PE_{32} = (3.4, 5.15, 6.85)$	$W_{32} = (0.5, 0.65, 0.8)$	$W_{321} = (0.2, 0.35, 0.5)$	$R_{321} = (2, 3.5, 5)$
				$W_{322} = (0.3, 0.5, 0.7)$	$R_{322} = (5, 6.5, 8)$
				$W_{323} = (0.5, 0.65, 0.8)$	$R_{323} = (3, 5, 7)$

(*continued*)

$\mathbf{PE}_i$	$\mathbf{W}_i$	$\mathbf{PE}_{ij}$	$\mathbf{W}_{ij}$	$\mathbf{W}_{ijk}$	$\mathbf{R}_{ijk}$
$PE_4 = (4.88, 6.38, 7.91)$	$W_4 = (0.7, 0.8, 0.9)$	$PE_{41} = (5.82, 7.07, 8.36)$	$W_{41} = (0.5, 0.65, 0.8)$	$W_{411} = (0.7, 0.8, 0.9)$	$R_{411} = (7, 8, 9)$
				$W_{412} = (0.5, 0.65, 0.8)$	$R_{412} = (5, 6.5, 8)$
				$W_{413} = (0.5, 0.65, 0.8)$	$R_{413} = (5, 6.5, 8)$
		$PE_{42} = (4.41, 6.04, 7.68)$	$W_{42} = (0.7, 0.8, 0.9)$	$W_{421} = (0.7, 0.8, 0.9)$	$R_{421} = (5, 6.5, 8)$
				$W_{422} = (0.5, 0.65, 0.8)$	$R_{422} = (3, 5, 7)$
				$W_{423} = (0.5, 0.65, 0.8)$	$R_{423} = (5, 6.5, 8)$
		$PE_{43} = (4.6, 6.12, 7.71)$	$W_{43} = (0.5, 0.65, 0.8)$	$W_{431} = (0.3, 0.5, 0.7)$	$R_{431} = (3, 5, 7)$
				$W_{432} = (0.7, 0.8, 0.9)$	$R_{432} = (5, 6.5, 8)$
				$W_{433} = (0.5, 0.65, 0.8)$	$R_{433} = (5, 6.5, 8)$
$PE_5 = (4.42, 6.03, 7.68)$	$W_5 = (0.3, 0.5, 0.7)$	$PE_{51} = (4.08, 5.67, 7.39)$	$W_{51} = (0.5, 0.65, 0.8)$	$W_{511} = (0.3, 0.5, 0.7)$	$R_{511} = (3, 5, 7)$
				$W_{512} = (0.7, 0.8, 0.9)$	$R_{512} = (5, 6.5, 8)$
				$W_{513} = (0.3, 0.5, 0.7)$	$R_{513} = (3, 5, 7)$
		$PE_{52} = (5, 6.5, 8)$	$W_{52} = (0.3, 0.5, 0.7)$	$W_{521} = (0.3, 0.5, 0.7)$	$R_{521} = (5, 6.5, 8)$
				$W_{522} = (0.2, 0.35, 0.5)$	$R_{522} = (5, 6.5, 8)$
				$W_{523} = (0.7, 0.8, 0.9)$	$R_{523} = (5, 6.5, 8)$

The FOPE index can be used to determine the supply chain practice effectiveness level of an airline catering organisation by matching the index with the different levels of overall practice effectiveness shown in Table 7.9. Table 7.9 shows seven levels of overall practice effectiveness on a qualitative scale ranging from 'Not Effective' to 'Distinctively Effective'. The matching algorithm used in this project is based on the Euclidean distance method and is described in Section 7.3.4.

Table 7.9 Fuzzy numbers for different levels of overall practice effectiveness

Overall Practice Effectiveness Level (OPEL)	Fuzzy number
Distinctively Effective (DE)	(8.5, 9.5, 10)
Very Highly Effective (VHE)	(7, 8, 9)
Highly Effective (HE)	(5, 6.5, 8)
Averagely Effective (AE)	(3, 5, 7)
Fairly Effective (FE)	(2, 3.5, 5)
Slightly Effective (SE)	(1, 2, 3)
Not Effective (NE)	(0, 0.5, 1.5)

7.3.4 Euclidean distance between FOPE and OPEL

The Euclidean distance method has been widely used in applications as a useful matching technique, and one of the advantages of the method is that it simply measures the distance between two points in the plane or multi-dimensional space (Vidyadhar *et al.*, 2016). In this research, the Euclidean distance method is used to calculate the distance between two data points for measuring similarities between FOPE and the levels in OPEL.

The Euclidean distance is calculated using Equation (7.4).

$$\mathrm{D}(\mathrm{FOPE}, \mathrm{OPEL}_i) = \left\{\sum \left(f_{FOPE}(x) - f_{OPEL_i}(x)\right)^2\right\}^{1/2} \quad \textbf{(7.4)}$$

This result of the Euclidean distance calculation is shown in Table 7.10. As an example, the calculation is applied to one of the overall practice effectiveness levels - 'Distinctively Effective', as follows.

$$\mathrm{D}(\mathrm{FOPE}, \mathrm{DE}) = \{(4.9 - 8.5)^2 + (6.31 - 9.5)^2 + (7.81 - 10)^2\}^{1/2} = 5.28$$

Table 7.10 Euclidean distance calculation results

Overall Practice Effectiveness Level	$f_{FOPE}(x)$	f_{OPEL_i}	$D(FOPE, OPEL_i)$
Distinctively Effective (DE)	(4.9, 6.31, 7.81)	(8.5, 9.5, 10)	D(FOPE, DE) = 5.28
Very Highly Effective (VHE)	(4.9, 6.31, 7.81)	(7, 8, 9)	D(FOPE, VHE) = 2.94
Highly Effective (HE)	(4.9, 6.31, 7.81)	(5, 6.5, 8)	D(FOPE, HE) = 0.28
Averagely Effective (AE)	(4.9, 6.31, 7.81)	(3, 5, 7)	D(FOPE, AE) = 2.45
Fairly Effective (FE)	(4.9, 6.31, 7.81)	(2, 3.5, 5)	D(FOPE, FE) = 4.92
Slightly Effective (SE)	(4.9, 6.31, 7.81)	(1, 2, 3)	D(FOPE, SE) = 7.55
Not Effective (NE)	(4.9, 6.31, 7.81)	(0, 0.5, 1.5)	D(FOPE, NE) = 9.88

The closest match between FOPE and the levels in OPEL is 'Highly Effective' (HE), as illustrated in Figure 7.2. Therefore, Company X is found to be highly effective regarding their airline catering supply chain's overall practice effectiveness.

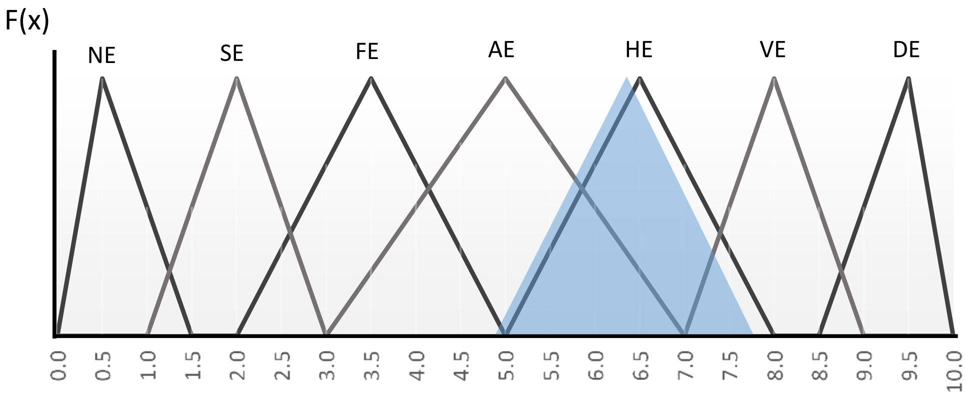


Figure 7.2 Linguistic levels to match OPELi

7.3.5 Proposals for Improvement

The PEEM can also be used to identify weak performing supply chain practices that impact overall practice effectiveness. The weak performing supply chain practices can be determined by calculating fuzzy performance importance index (FPII) that combines performance rating and the importance weight of a supply chain practice into a single index. The lower a supply chain practice's FPII score, the lower is its rank in contributions to the overall practice effectiveness of an organisation. FPII is calculated using Equation (7.5):

$$\text{FPII} = W'_{ijk} \otimes R_{ijk} \quad \textbf{(7.5)}$$

W'_{ijk} = Complement of the importance weight of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.

= $[(1,1,1) - W_{ijk}]$, where W_{ijk} is the importance weight of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.

R_{ijk} = Performance rating of k^{th} supply chain practice in j^{th} practice category in i^{th} performance attribute.

For example, the FPII_{111}, in Table 7.11 for PE_{ijk}, R_{ijk} and W_{ijk}, where *i*=1, *j*=1 and *k*=1 is calculated as follows.

$$\text{FPII}_{111} = (0.1, 0.2, 0.3) \otimes (7, 8, 9)$$
$$= (0.7, 1.6, 2.7)$$

FPII for the supply chain practices is shown in Table 7.11. The supply chain practices are ranked based on the FPII values. To rank order fuzzy numbers, the centroid method (Mehdizadeh, 2010) applied to TFNs can be used to calculate the centroid of each fuzzy number. The ranking score is calculated using Equation (7.6), where, as before, a, b, and c are the lower, middle, and upper values of the triangular fuzzy number, respectively.

$$\text{Ranking score (RS)} = \frac{a + 4b + c}{6} \qquad \textbf{(7.6)}$$

For example, the ranking score RS_{111} is calculated as follows.

$$\text{RS}_{111} \frac{0.7 + 6.4 + 2.7}{6} = 1.63$$

The ranking scores for the supply chain practices of Company X are shown in Table 7.11.

Table 7.11 Fuzzy performance importance index and ranking score for supply chain practices of Company X

$\mathbf{PE_{ijk}}$	$\mathbf{R_{ijk}}$	$\mathbf{(1,1,1) - W_{ijk}}$	$\mathbf{FPII_{ijk}}$	$\mathbf{RS_{ijk}}$
PE_{111}*	(7, 8, 9)	(0.1, 0.2, 0.3)	(0.7, 1.6, 2.7)	1.63
PE_{112}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35
PE_{113}*	(3, 5, 7)	(0.2, 0.35, 0.5)	(0.6, 1.75, 3.5)	1.85
PE_{121}*	(7, 8, 9)	(0.1, 0.2, 0.3)	(0.7, 1.6, 2.7)	1.63
PE_{122}*	(3, 5, 7)	(0.2, 0.35, 0.5)	(0.6, 1.75, 3.5)	1.85
PE_{123}	(7, 8, 9)	(0.3, 0.5, 0.7)	(2.1, 4, 6.3)	4.07
PE_{131}	(7, 8, 9)	(0.2, 0.35, 0.5)	(1.4, 2.8, 4.5)	2.85
PE_{132}	(5, 6.5, 8)	(0.3, 0.5, 0.7)	(1.5, 3.25, 5.6)	3.35
PE_{133}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{211}*	(5, 6.5, 8)	(0.1, 0.2, 0.3)	(0.5, 1.3, 2.4)	1.35
PE_{212}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35

PE_{213}^{*}	(3, 5, 7)	(0.2, 0.35, 0.5)	(0.6, 1.75, 3.5)	1.85
PE_{221}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{222}^{*}	(5, 6.5, 8)	(0.1, 0.2, 0.3)	(0.5, 1.3, 2.4)	1.35
PE_{223}	(5, 6.5, 8)	(0.3, 0.5, 0.7)	(1.5, 3.25, 5.6)	3.35
PE_{231}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{232}^{*}	(7, 8, 9)	(0.1, 0.2, 0.3)	(0.7, 1.6, 2.7)	1.63
PE_{233}^{*}	(7, 8, 9)	(0.1, 0.2, 0.3)	(0.7, 1.6, 2.7)	1.63
PE_{311}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{312}	(5, 6.5, 8)	(0.3, 0.5, 0.7)	(1.5, 3.25, 5.6)	3.35
PE_{313}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35
PE_{321}	(2, 3.5, 5)	(0.5, 0.65, 0.8)	(1, 2.275, 4)	2.35
PE_{322}	(5, 6.5, 8)	(0.3, 0.5, 0.7)	(1.5, 3.25, 5.6)	3.35
PE_{323}^{*}	(3, 5, 7)	(0.2, 0.35, 0.5)	(0.6, 1.75, 3.5)	1.85
PE_{411}^{*}	(7, 8, 9)	(0.1, 0.2, 0.3)	(0.7, 1.6, 2.7)	1.63
PE_{412}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35
PE_{413}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35
PE_{421}^{*}	(5, 6.5, 8)	(0.1, 0.2, 0.3)	(0.5, 1.3, 2.4)	1.35
PE_{422}^{*}	(3, 5, 7)	(0.2, 0.35, 0.5)	(0.6, 1.75, 3.5)	1.85
PE_{423}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35
PE_{431}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{432}^{*}	(5, 6.5, 8)	(0.1, 0.2, 0.3)	(0.5, 1.3, 2.4)	1.35
PE_{433}	(5, 6.5, 8)	(0.2, 0.35, 0.5)	(1, 2.275, 4)	2.35
PE_{511}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{512}^{*}	(5, 6.5, 8)	(0.1, 0.2, 0.3)	(0.5, 1.3, 2.4)	1.35
PE_{513}	(3, 5, 7)	(0.3, 0.5, 0.7)	(0.9, 2.5, 4.9)	2.63
PE_{521}	(5, 6.5, 8)	(0.3, 0.5, 0.7)	(1.5, 3.25, 5.6)	3.35
PE_{522}	(5, 6.5, 8)	(0.5, 0.65, 0.8)	(2.5, 4.225, 6.4)	4.30
PE_{523}^{*}	(5, 6.5, 8)	(0.1, 0.2, 0.3)	(0.5, 1.3, 2.4)	1.35

To identify and analyse the supply chain practices that impact the overall practice effectiveness, the management threshold value of 2 has been set by the senior management team of Company X. This enables the company to identify 16 weak performing practices in their airline catering supply chain, which have a lower performance score than the management's threshold value. The 16 weak performing practices are listed in Table 7.12.

Table 7.12 Weak performing practices

Barcoding/RFID	Master data accuracy
Baseline inventory monitoring	Picklist generation
Bill of material audit/control	Production scheduling optimisation
DMAIC practice	Sales and operations planning
Employee training	Scenario planning
Gemba walks	Standard operating procedures
Lean	Strategic sourcing
Logistics & warehouse planning	Transportation management system

7.4 Discussion and Implication

7.4.1 Discussion

Company X is performing well in some of its supply chain practices in relation to overall supply chain practice effectiveness measured by PEEM. The seven practices of Company X listed in Table 7.13 have a ranking score that is above 3. The focus group used in this research recognised business rule management and generation of dynamic bills of materials as highly valuable practices in their airline catering supply chain. The business rule defines the airline catering service strategy stated in Chapter 1 by addressing critical questions like 'which is the service flight', 'what meal service to offer', 'how to assemble meals in the container', and 'where to load catering containers in aircraft galley' (Jones, 2012a). Generation of dynamic bills of materials facilitates producing flight labels (container assembly task labels-CAT labels) for assembly operations according to flight schedules and change requests such as passenger numbers and meal preferences.

Table 7.13 High performing practices

Automated Data Capture	Return Load Optimisation
Batch Size Reduction	Supplier Research
Business Rule Management	Supply Chain Risk Assessment
Generation of Dynamic Bills of Materials	

Enterprise systems are the key enabler for business change and digital transformation in organisations (Baiyere *et al.*, 2020). An effective logistics execution system is necessary to deliver airline catering service that improves customer satisfaction successfully. Better access to and use of airline catering information is key to strengthening catering management and building logistics service capacity in the airline catering supply chain (Gschirr, 2010). Airline catering organisations should investigate the potential of reconfiguring and customising their systems to support current business needs and design solutions for their business specific requirements.

Improvement in planning and data capture systems are some of the weak performing practices in Company X. Sales and operations planning, logistics and warehouse planning, and scenario planning are three areas of planning identified as weak supply chain practices of Company X. Airline catering operations' characteristics such as changing menu specifications, high volatile passenger numbers and meal requests, and dynamic tray service units (TSU) operations make the planning process more difficult (Jones, 2012a). Company X currently use a barcoding system. Barcoding systems are known to have challenges such as misreads due to damage or obstruction, issues with printer maintenance, being only able to store small data and requiring read at line of sight (Thanapal *et al.*, 2017). Adopting a better data capture system such as RFID will help Company X increase their data accuracy and improve associated supply chain practices (Schmidt *et al.*, 2013). Company X needs to streamline logistics operations within their system framework and integrate systems effectively. It is necessary to integrate resource planning, warehouse management, and transport management business processes for improved supply chain management and effective decision making across different functional areas (Rajaratnam and Sunmola, 2020a). Integrated enterprise systems can improve airline catering service effectiveness and reduce overall operating costs by enabling best practices such as sales and operations planning, production scheduling optimisation, and logistics and warehouse planning. It is important to consider factors such as inventory storage size, airline catering production, catering waste and set-up time to develop optimal production and inventory allocation strategy for sustainability enhancement in the airline catering supply chain (Andiappan *et al.*, 2021). It is also important for an airline catering organisation to implement appropriate master data management methodology. This will ensure that master data is coordinated across the organisation. It will also provide accurate, complete and consistent menu plan, galley plan, meal rules, and flight schedule data across departments and share with airlines, food and non-food suppliers.

Lean practices and continuous improvement are important, including DMAIC and Gemba walk (Noronha *et al.*, 2021). It is good to conduct a Gemba walk at different times of the day and on different days of the week to get a complete view of the catering operations. Airline catering organisations should select the right project to focus on regarding process improvement before applying the DMAIC approach. It would be better to invite employees to suggest projects that might benefit from lean process improvement, DMAIC, and reducing catering service costs or improving the quality of catering service (Soundararajan and Janardhan Reddy, 2019). Continuous improvement tools like SIPOC diagrams, value stream maps and fishbone diagrams can be of great use as they will help collect and structure related data, calculate results and improve communications during the DMAIC project. Continuous improvement approaches like DMAIC and Lean require discipline. Appointing a continuous improvement (CI) manager who can be in charge of the projects and help develop CI culture and mindset across the organisation will make the operations team comfortable with these approaches (Lleo *et al.*, 2017). CI managers can facilitate regular coaching and workshops that will enable airline catering organisations to create positive changes quickly and efficiently. For Company X, these areas, i.e., Gemba walk, DMAIC and Lean, are weak practice areas.

There is evidence in the literature that the implementation of supply chain practices can be associated with better supply chain performance. This chapter indicates that the airline catering supply chain that successfully adopts the SCOR practices can benefit from those practices as they can straightforwardly evaluate their practice effectiveness and identify weak performing areas. Achieving and maintaining distinctive practice effectiveness can be challenging as it requires continuous improvement in practices.

The weighting used in evaluating practice effectiveness was based on the experts' view of their supply chain and industry. For example, the experts' importance weight rating reveals that responsiveness and cost performance attributes have high importance in the airline catering supply chain, which aligns with the view from the literature regarding the importance of the timeliness factor (Deepa *et al.*, 2021) and cost pressure in the airline catering business (Rajaratnam and Sunmola, 2021b).

7.4.2 Implication

The case study reported in this chapter is from a specific sector where it is possible to discuss the business context and the considerations of proposing reasonable supply chain practices for the airline catering industry and linking them with performance attributes. Although only one sector has been examined, the research considered mainstream supply chain practitioners through the SCOR model and used generic supply chain management practices. Therefore, the evaluation framework may be applied to other industry sectors in any country with some refinement and/or contextualisation.

In terms of practical and managerial implications, with the knowledge of the effectiveness of supply chain practices, supply chain practitioners can carry out investigations and benchmark the degree of adoption of supply chain practices relevant to their organisation objectives, and thus direct efforts to improve the supply chain performance. First, the PEEM needs to be explained to the senior management regarding the organisation's measurement for supply chain practice effectiveness and how its business processes benefit. Once the management has endorsed the PEEM for assessment, the performance ratings and importance weights for various performance attributes, practice categories and supply chain practices from responses of relevant management staff will be used to compute the FOPE and FPII. If the FOPE is found to be less than distinctively effective practice, then the barriers (low performing practices) must be identified and improved to increase the organisation's overall supply chain practice effectiveness. Organisation management can set the threshold value for FPII and can identify weak performing practices to take necessary actions. Once the improvement steps are implemented, the organisation's effectiveness level should be measured again using the evaluation model to identify any further enhancements required. The threshold plays an important role in identifying improvement areas. In this research, the senior management of Company X was tasked with the decision of specifying the threshold, and this requires appropriate insights into the company's business and vision.

This thesis chapter contributes to an understanding of supply chain management practices and practice effectiveness. The effectiveness evaluation model proposed in this chapter is measured using fuzzy logic to remove inadvertent ambiguity and vagueness in the decision-making process (Kumar *et al.*, 2013). In addition, organisations can use fuzzy approaches to help management achieve operational excellence using better decision-making models. Further, this research promotes a simple evaluation model by avoiding calculation complexity. Therefore, the key contributions of the evaluation model are a new approach to assess supply chain practice effectiveness based on the SCOR model, FOPE and FPII; and the identification of weak performing supply chain practices. Supply chains planning for new supply chain practice adoption can assess their effectiveness, identify weak areas and address those barriers leading to effective implementation of supply chain practices for better performance.

7.5 Chapter Summary

This chapter presents a conceptual model for assessing supply chain practice effectiveness. The conceptual model developed in this chapter is illustrated using the supply chain performance attributes, practice categories, and supply chain practices from the SCOR v12 framework adopted by the case study company. Supply chain practice effectiveness assessment is carried out using a fuzzy logic approach. The calculations are demonstrated by applying the evaluation model to Company X, an airline catering organisation in the U.K. The inputs from industry experts have been obtained using the linguistics variables, and fuzzy triangular numbers have been defined to compute the overall practice effectiveness. FOPE is found to be (4.9, 6.31, 7.81). The case study airline catering organisation is found to be “Highly Effective”. The method also identifies the weak performing practices by computing FPII for different supply chain practices and proposes to take appropriate actions for the overall effectiveness improvement of the airline catering supply chain. Finally, the chapter discusses the case study results and the implication of the evaluation model.

8 Conclusion and Future Work

This chapter discusses the concluding remarks based on the solutions developed and the results reported in the previous chapters in this thesis. As stated earlier, logistics plays a vital role in this airline catering supply chain. Airline catering companies needed to redesign their supply chain processes, develop new performance measures, and implement supply chain best practices to make their logistics more efficient.

In the initial stage of the research process, this research study analysed the logistics operations processes and designed business process models for integrating logistics processes and enabling data flow across different functional areas to better configure and leverage information systems for airline catering logistics operations. The investigative research approach reviewed the current logistics processes and supply chain systems, analysed the sequence or flow of logistics activities within the supply chain, and identified process integration needed for the specific business requirements to design business process models for the airline catering logistics operation. The analysis study documented the current state process analysis to summarise the findings of a review of logistics operations at the case study airline catering organisation by outlining the existing methods, tools, issues and opportunities. SIPOC tool was used for documenting business processes from beginning to end in all warehouse operations and food assembly operations areas. SIPOC is a high-level diagram that provides a structured way to define the process. The researcher used this visual tool to discuss and identify the processes through focus group sessions.

This thesis is designed to build a roadmap and also become an applicable solution. It provides the road map for guiding airline catering organisations to progress towards the journey of an effective and efficient supply chain execution, as expressed in the background and motivation section in Chapter 1. Nevertheless, this thesis document is a reference guide for representing, configuring, executing, and analysing airline catering logistics processes, defining and prioritising performance measures, evaluating existing supply chain practice effectiveness, and providing an evaluation approach applicable to the airline catering industry.

The chapter is divided into five sub-sections. Section 8.1 outlines the completion of the research objectives and findings of the thesis. Section 8.2 explains the concluding remarks of the three projects covered in this research; process modelling, performance metrics development, and practice effectiveness evaluation. Section 8.3 highlights the practical implications and Section 8.4 stresses the limitations of the research study. The last Section 8.5, recommends future directions of the research.

8.1 Research Objectives and Main Findings of the Study

The primary aim of this research was to investigate the business processes of the airline catering supply chain and develop an approach for evaluating airline catering supply chain practice effectiveness based on performance considerations. In order to achieve this aim, the below objectives were set out in the research design during the initial stage. Each objective has been addressed as progress towards the journey of achieving the overall research aim.

1. Explain the airline catering supply chain landscape, the opportunities and challenges it presents.

This objective was accomplished. The research study analysed the airline catering supply chain literature in the initial phase. Further, it revealed findings from the case study. It added more facts to the existing body of knowledge by examining the unique characteristics, operational challenges, and emerging airline catering supply chain trends.

2. Design a business process architecture for airline catering logistics based on the SCOR model, and identify the underlying processes and associated process maps.

The research achieved this objective. It was investigated through a case study how the business activities along the catering order fulfilment can be realised through business process integration. The research has developed a process design framework and applied it to this case study. The research developed a full design based on an airline catering requirements specification and modelled core logistics processes like procurement, production, and fulfilment.

3. Establish SCOR-based performance metrics relevant to the airline catering supply chain.

The objective was realised by applying the SCOR framework in the context of the airline catering supply chain. This research has developed the airline catering SCOR model and established a hierarchical framework for performance measurement, and a set of 55 performance metrics, including Level 1 strategic metrics and Level 2, and 3 diagnostic metrics based on the SCOR framework are proposed for airline catering logistics service.

4. Examine the influence of uncertainties as presented by the COVID-19 pandemic on the prioritisation of SCOR-based performance metrics in airline catering logistics and discuss the key considerations.

This objective has been completed by studying an airline catering organisation during the COVID-19 pandemic. The research has analysed the impacts of COVID-19 on the airline catering supply chain. The research obtained the viewpoints from industry experts to understand the changes in performance considerations and proposed the MoSCoW prioritisation technique for performance metrics choices during such uncertainties.

5. Develop an approach for assessing airline catering supply chain practice effectiveness and for identifying areas requiring improvement.

This objective was achieved. This research study has developed a practice effectiveness evaluation model (PEEM) using fuzzy logic to assess the supply chain practice effectiveness in the airline catering supply chain. The model also helps identify the weak performing practices by computing the fuzzy performance importance index to improve the overall practice effectiveness continuously.

The research focused on three key areas that are likely to influence the supply chain effectiveness in airline catering. Research objectives were defined clearly to focus on these supply chain areas of processes, performance and practices. Three projects are completed to develop solutions for each focus area, and the concluding remarks are described in Section 8.2 below.

8.2 Concluding Remarks

This study has added new contributions to the existing literature on airline catering, and its supply chain operations since the research in this field remain limited, and very little relevant literature is available. This research contributes to both the literature on airline catering operations and the supply chain management literature by recognising some critical research areas related to both fields. Furthermore, this study helps academic researchers and business leaders better understand the complexity of supply chain management in the airline catering service and concludes that airline catering organisations should consider supply chain management as a strategic function that offers enormous potential for improving service effectiveness and adding economic value for airline catering industries. Firstly, the case study was about supply chain and logistics operations in the airline catering business. Airline catering is one of the complex operations. Hence, this study should enhance the knowledge of the supply chain in the airline catering industry. The results of the projects covered in this research study are expected to benefit both the airline catering industry and academia.

8.2.1 Process Modelling

The business process design approach developed in this research contributes to achieving ideal cross-functional integration to streamline separate business processes while ensuring greater visibility of airline catering logistics operations. The project analysed the logistics operations processes and designed a process architecture and business process models based on the SCOR framework to help the airline catering organisations develop an integrated solution for airline catering logistics operations. BPD approach proposes a solution design that promotes a business process integration technique to logistics service for an effective airline catering supply chain. A detailed analysis of the airline catering business identifies the primary integration points between and among logistics processes. The approach uses BPMN visual modelling language, the global standard for analysing and modelling business processes, which will help airline catering supply chain practitioners adopt and apply an integrated perspective to airline catering business processes.

The process modelling research project produces a blueprint to implement full-scale logistics functionalities within an information system at the case study organisation to manage its increasingly complex logistics operations. Design and implementation of a new integrated solution for airline catering logistics operations using the SCOR framework is an opportunity to bring Company X's service centre's food assembly operations and warehouse operations closer together in many ways. The results of this research study enhance Company X's understanding of conceptual and application issues of information systems in the airline catering business environment, help optimise existing supply chain system deployment or implement an effective integrated solution for logistics execution to enhance operational excellence and resource efficiencies in the airline catering supply chain.

8.2.2 Performance Metrics Development

There are some key contributions of developing performance metrics based on the SCOR model and prioritising the choice of metrics during an emergency in the airline catering supply chain. The work contributes to measuring performance in the airline catering supply chain and the need for considering adapting performance metrics using techniques such as MoSCoW, during challenging periods as in the COVID-19 pandemic.

This research has been conducted in one of the large airline catering organisations to examine their logistics service provisioning and to propose an approach to improve the effectiveness of their airline catering logistics service. The researcher has used the SCOR model to examine and map the airline catering supply chain processes because of its easily adaptable and customisable features. The SCOR model was extended to be more suitable for the airline catering environment by linking SCOR performance attributes with airline catering logistics performance. SCOR framework provides over 300 metrics classified under five performance attributes to monitor supply chain performance. But it is precisely this diverse set of performance metrics that can confuse airline catering business managers.

In different disruptive situations like the COVID-19 pandemic, airline catering practitioners may need to know when to emphasise certain performance metrics. SCOR-based metrics and prioritisation will help the airline catering organisation to focus on particular performance metrics. They can keep the airline catering supply chain more adaptable and flexible in responding to the market changes in the aviation industry and manage product and service costs more efficiently, especially during disruptive periods such as the COVID-19 pandemic. It is concluded prioritisation techniques, e.g. MoSCoW will help the airline catering supply chain performance metrics considerations during an emergency such as the COVID-19 pandemic to help better manage their service deliveries and effectiveness in highly uncertain times. COVID-19 challenges disrupted many industries, including the airline catering industry. The consequence of these challenges needs for the airline catering supply chain to adapt its performance metrics. With the development of performance metrics and the prioritisation presented in this research, airline catering organisations can monitor their catering logistics performance and use techniques such as MoSCoW to decide on performance measures priorities in situations such as the COVID-19 pandemic.

The research objectives achieved from this study are the set of metrics that can be used to define key performance indicators for the logistics service within the airline catering organisation. These strategic level evaluation metrics serve as diagnostic tools to examine the overall effectiveness of the airline catering supply chain and help airline catering organisations to establish performance targets more realistically.

8.2.3 Practice Effectiveness Evaluation

The airline catering supply chain is increasingly facing competitive pressure. As a result, they need to adopt effective practices, which will lead to improved performance. The main contribution of the practice effectiveness study is developing a practice effectiveness evaluation model (PEEM) for assessing the supply chain practice effectiveness. It proposes an effectiveness evaluation approach that measures the overall practice effectiveness level of the organisation (FOPE). Further, the analysis computes the fuzzy performance importance index (FPII) and helps rank low-performing practices according to their FPII score.

This research has presented an approach for assessing supply chain practice effectiveness using fuzzy logic. Fuzzy logic provides an effective solution to overcome any limitations in the evaluation approach due to complexity and uncertainty. The study focuses on addressing the question of how supply chain effectiveness can be evaluated in the airline catering industry. It developed a conceptual model comprising three levels, using the supply chain performance attributes, practice categories, and supply chain practices described in the SCOR framework. The practice effectiveness measurement can be calculated using this model. The fuzzy logic-based evaluation method was validated in the airline catering case study company. The inputs from industry experts have been obtained using the linguistics variables, and fuzzy triangular numbers have been defined to compute the overall practice effectiveness. FOPE is found to be (4.9, 6.31, 7.81) for the case study company in this research. The effectiveness level was determined using the Euclidean distance method, and the case study company was found to be highly effective and open to some areas of practice improvement. FPII for different supply chain practices were computed, and 16 practices were found to be weaker performance based on a specified threshold. For weak performing practices, appropriate actions should be taken to improve the overall practice effectiveness of the airline catering supply chain. The use of fuzzy logic in this evaluation model eliminates unnecessary ambiguity and vagueness in the data used in the evaluation process. It's concluded that fuzzy logic-based evaluation of practice effectiveness is simple and easy to understand and can be used by supply chains that adopt the SCOR framework, as demonstrated in this chapter for airline catering supply chain. In addition, it is concluded that airline catering supply chain should pay attention to continuous improvement of their supply chain practice effectiveness, and the fuzzy logic-based approach presented in Chapter 7 can help identify the areas of practice for improvement through continuous assessment.

8.3 Practical Implications

Process modelling research suggests a business process integration approach, proposes a business process modelling framework and develops business process models based on the SCOR framework to support the implementation of full-scale airline logistics functionalities for airline catering organisations to manage their increasingly complex logistics operations. For the practical implication, the SCOR-based process reference model is, of course, quite convenient for communicating the business needs and functional requirements with accuracy and no ambiguity, thus increasing the understanding and adoptability of process analysis and design approach for customising, enhancing, or implementing a logistics execution system for the airline catering business.

Performance metrics study found that performance measurement considerations in the airline catering supply chain have been changed during the COVID-19 pandemic. The SCOR metrics prioritisation results of the study suggests that airline catering organisation is putting more emphasis on measuring performance relate to responsiveness attribute and, plan and enable supply chain management processes during the COVID-19 disruption, as they are highly effective in managing the supply chain and respond to the effect of uncertainties presented by the COVID-19 pandemic. The cited findings have the practical implication that the choice of

SCOR performance metrics is critical in the continuing management of logistics and supply chain performance in airline catering service during emergencies.

The practical implication of the practice effectiveness study is that we can compute the overall supply chain practice effectiveness of an airline catering organisation and identify focus areas for continuous improvement. The measurement of supply chain practice effectiveness factors to get the appropriate value of overall practice effectiveness can define the effectiveness level of the airline catering organisation, and computing fuzzy performance importance index may help management to identify low-performing SCOR supply chain practices in airline catering supply chain to take improvement actions. This helps in developing a shared understanding of SCOR supply chain management practices and their impacts on airline catering service.

8.4 Limitations of the Study

The limitation of process design in this thesis is its industry adaptability and suitability, which have not been tested yet. It's restricted to the business process modelling only, based on a case study of an airline catering service provider in the U.K. As there is no direct implementation of the logistics execution system from the proposed business process models, it is necessary to evaluate the applicability of the model through future research. However, there are limited organisations in the airline catering business, and implementing business process integration is also a big project. Therefore, there may be some challenges in getting ideas and confirmation from experts in this field to validate the quality of business process modelling and its relevance to the airline catering business.

The researcher also acknowledges some of the limitations of the performance metrics development research study. This research is motivated by a single case study, and the proposed metrics development is based on the deep level of analysis of one airline catering organisation. The research reported in Chapter 6 is based on a limited number of participants, which impacts the generalisability of the results. Hence, its industry adaptability and suitability need to be assessed outside the organisation.

Moreover, PEEM developed in practice effectiveness research study (described in Chapter 7) was tested in a single airline catering organisation. Therefore, more studies need to be carried out in different airline catering organisations to ensure the reliability and industrial applicability of the evaluation model. This method can be extended by integrating into airline catering supply chain analytics with emerging statistical techniques, predictive modelling, and machine learning to support automated evaluation of practice effectiveness. It can help airline catering organisations to make the right decision by attaching a particular importance level to certain performance attributes based on airline customer preferences and trends. Accordingly, it can help organisations to put more emphasis on selected practices on a short and long-term basis to improve operational efficiency.

8.5 Future Directions

The process model reported in Chapter 5 doesn't incorporate actual implementation. The scope of the project expressed by the company was to design business process models and give some insights into business process integration. Whilst the company focused on the design of integrated business process models, they are considering the implementation of the design as future work, particularly when the required resources are available and when the contractual arrangements with their customers are in place. Further research for a wide assessment of many airline catering companies can be performed in order to validate that the design is standardised and is being adaptable in the airline catering industry. The appropriateness of process models can be assessed using a delphi study method. Process modelling study only focuses on logistics operations for this thesis, and the researcher recommends further research on other functional areas of the airline catering company such as airline catering equipment management, galley and stowage planning, human resource management, finance, etc.

The performance metrics development study could be further expanded across many other airline catering organisations using the case study approach to define a comprehensive industry benchmark for their supply chain performance. Furthermore, quantitative research methodology can be embedded into this type of research to analyse performance information and to investigate the industry-wide efficiencies covering end-to-end airline catering supply chain in the future. Areas of future work include the extension and validation of the performance metrics development approach presented in this research and seeking to generalise a framework for adapting SCOR-based performance metrics during the challenging period, such as those presented by the COVID-19 pandemic. MoSCoW prioritisation technique was found to be useful for the quick classification of performance metrics. However, further investigation into the robustness of this method and more systematic research is required to make reliable claims regarding its applicability to the widespread supply chain disciplines. The performance metrics prioritisation would benefit greatly from future research that establishes clear guidelines for its best use.

In future practice effectiveness research, evaluation can be applied to the supply chain in other industry sectors such as automotive, retail, telecom, manufacturing, and healthcare industries that use the SCOR model. A triangular fuzzy number (TFN) approach has been used in this study; other types of fuzzy logic methods such as Trapezoidal Fuzzy Number (TrFN), and Gaussian Fuzzy Number (GFN) can be explored and incorporated into this evaluation model in the future. Also, methods of determining the threshold for identifying areas of practice improvement in the airline catering supply chain should be developed. The framework presented in Chapter 7 could be extended to evaluate green supply chain management practices for sustainable supply chain performance. Particularly, the PEEM can be exploited to cover the airline catering sustainability effectiveness by assessing the sustainable supply chain practices to tackle emerging global sustainability issues such as catering waste and the environmental impact of operations and processes.

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Appendix

Appendix A – Interview questions for understanding the catering operations

A.1 Questions used for interviews

Service

1. How many flights are catered for each day? Which sector of the flight (Outbound / Inbound)?
2. What kind of services does this catering service centre offer (Food/BAR/Equipment)?
3. How many cabin classes do you serve meals? What exactly are they?
4. How many meal services are there in each sector?

Menu Planning/Demand Planning

5. How do you get airline catering orders?
6. How far in advance do you receive airline catering orders?
7. What is the time limit for processing catering orders?
8. What is the procedure for dealing with late catering requirements after the cut-off period?

Materials Management

<u>Food</u>

9. How do you place purchase orders?
10. How are these ordered meals received and added to stock (via system)?
11. How are these stocks consumed by flight orders in the system?
12. How do you manage/track inventory for various customers/services?
13. Do you recycle your meals? How do you manage the process?

<u>BAR</u>

14. Do you purchase them? Or manage customers' stock?
15. How does the ordering/good receipting/stock management procedure work?
16. How do you handle recycling and reuse?

<u>Equipment</u>

17. Do you purchase them? Or manage customers' stock?
18. How does the ordering/good receipting/stock management procedure work?
19. How do you handle recycling and reuse?

Sales Management

20. How does the operations team determine the catering needs for each flight?
21. Do you have the ability to track consumption by individual flight?

Production Planning / Management

22. What is the strategy (Push/Pull) of food assembly and warehouse operations?
23. How does the operations team replenish inflight products and build catering containers based on catering requirements?

Galley Planning

24. How do you get the packing plan from the airlines?
25. How does the operations team meet the catering requirements outlined in the packing plan?

Systems

26. What information technology systems and tools do you currently use to support catering operations?
27. What functionalities do these systems currently provide?

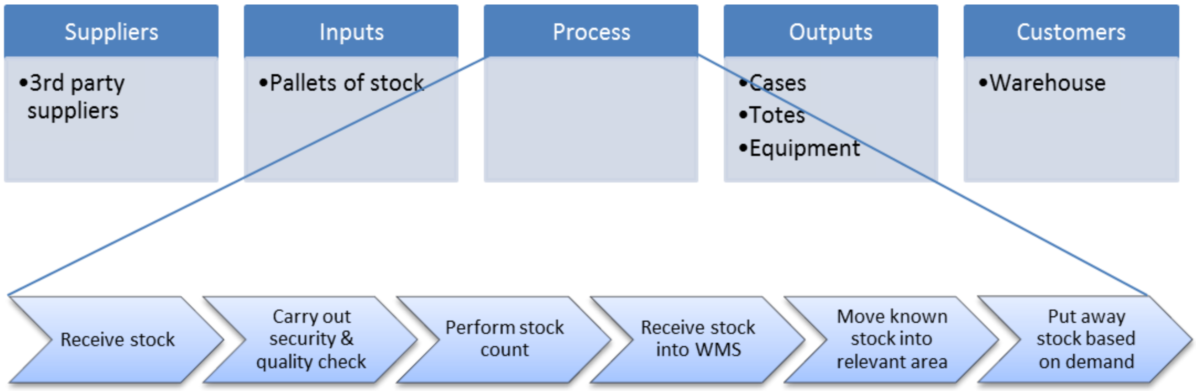
Transport

28. How many vehicles do you use per day for each airline?
29. What is the capacity of the catering truck? How many services/flights can be catered by one truck?

A.2 SIPOC diagram as a data collection tool

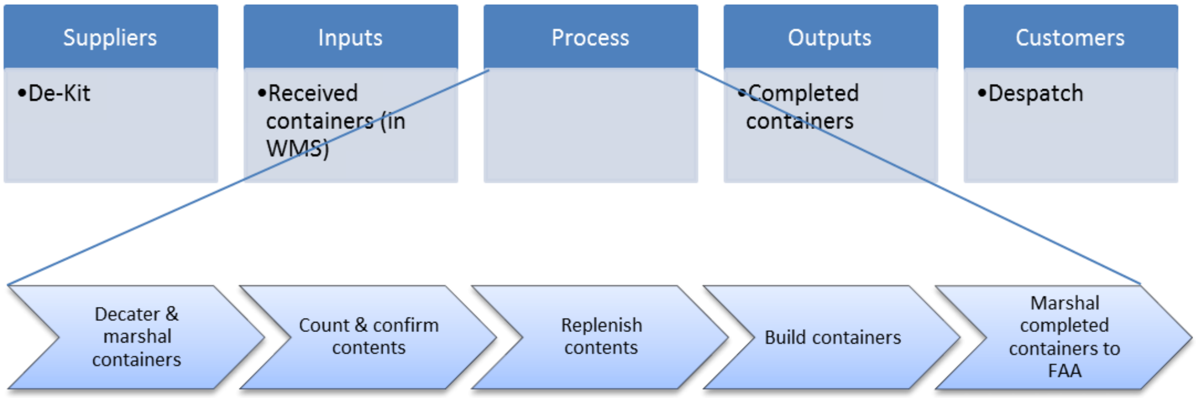
Warehouse Operations

1. **Goods In**



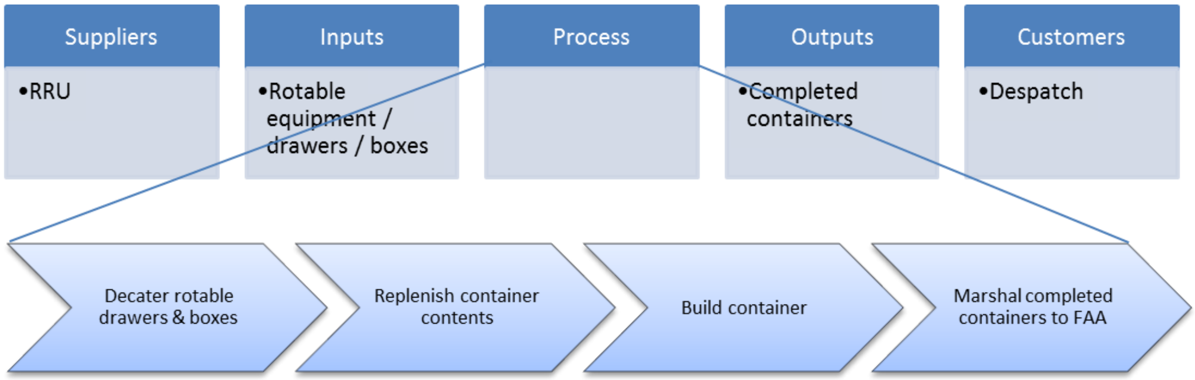
SIPOC Diagram – Goods In Process

2. **CLS-Carton Live Storage**



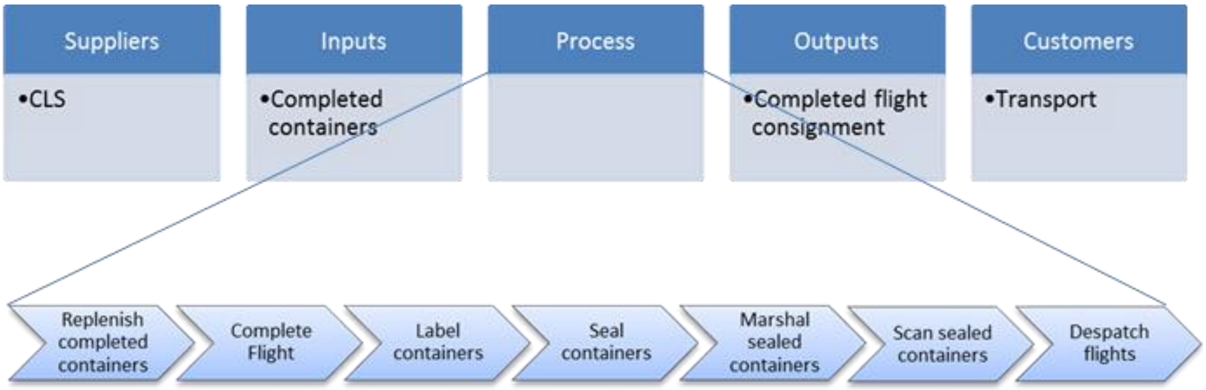
SIPOC Diagram – CLS Process

3. WES-Warehouse Equipment Storage



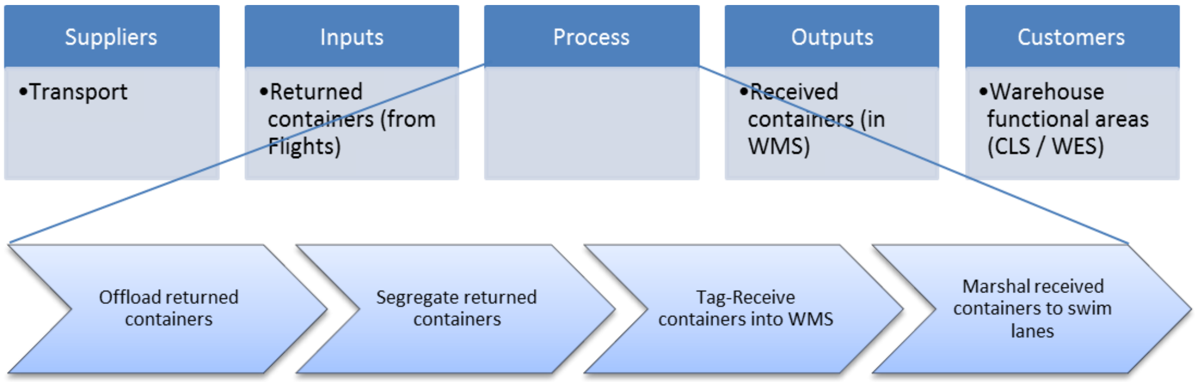
SIPOC Diagram – WES Process

4. Despatch



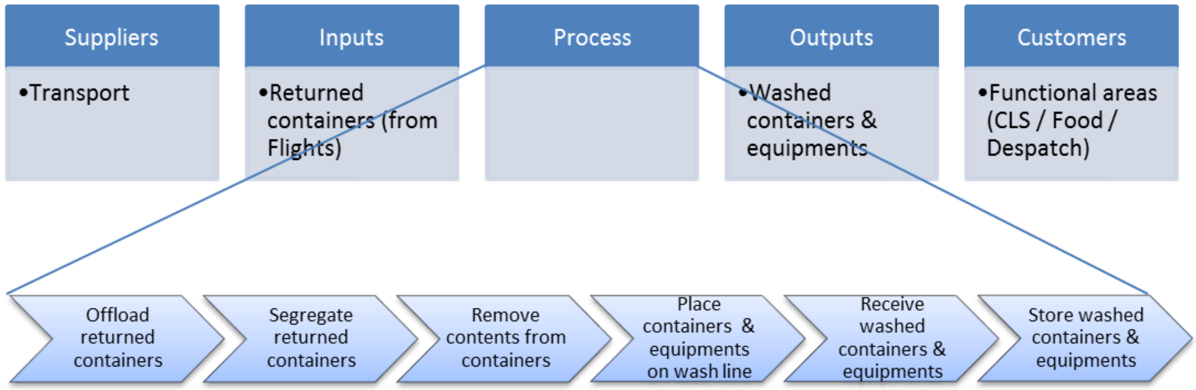
SIPOC Diagram – Despatch Process

5. De-Kit



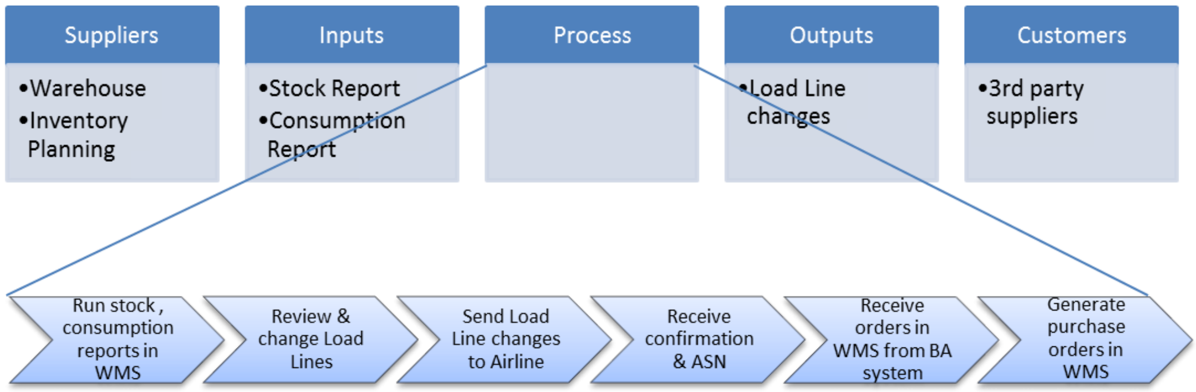
SIPOC Diagram – De-Kit Process

6. RRU – Return and Recycling Unit



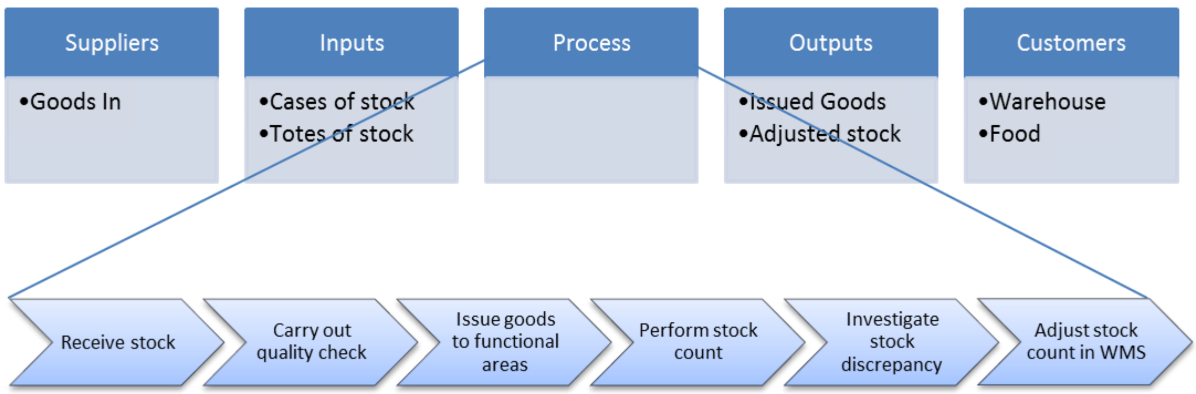
SIPOC Diagram – RRU Process

7. Booking In



SIPOC Diagram – Booking In Process

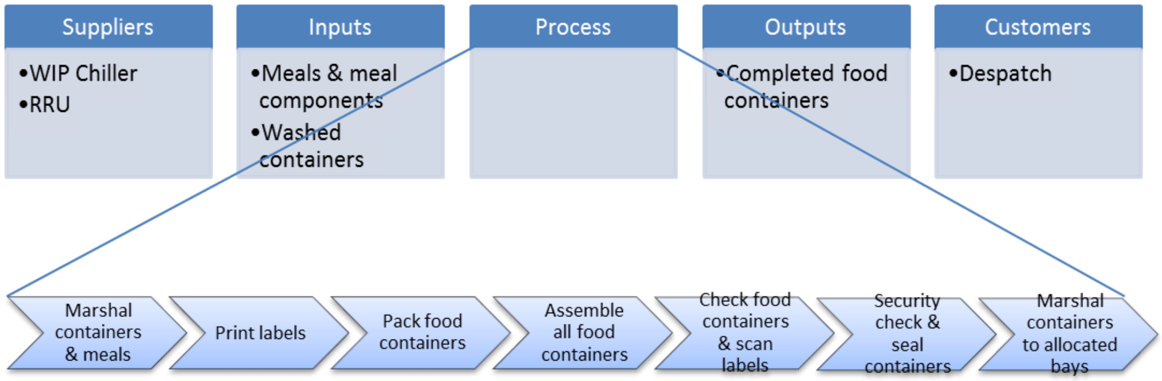
8. Inventory



SIPOC Diagram – Inventory Process

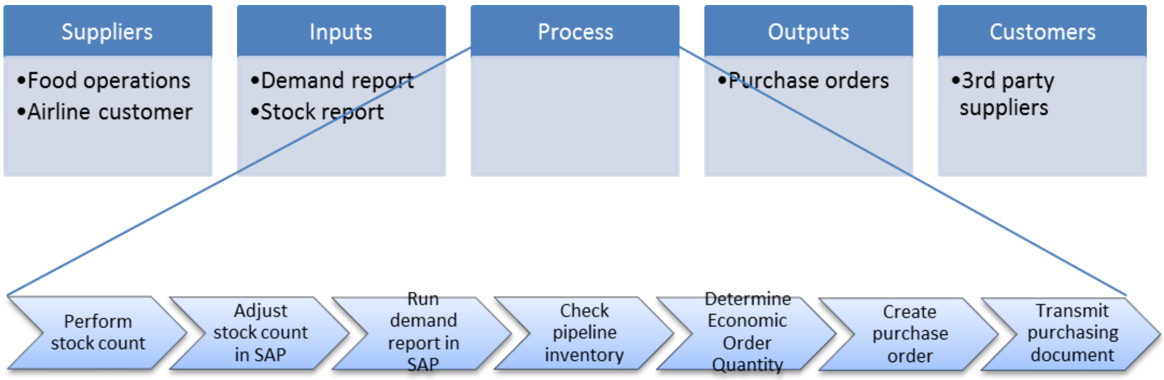
Food Assembly Operations

1. Food Assembly



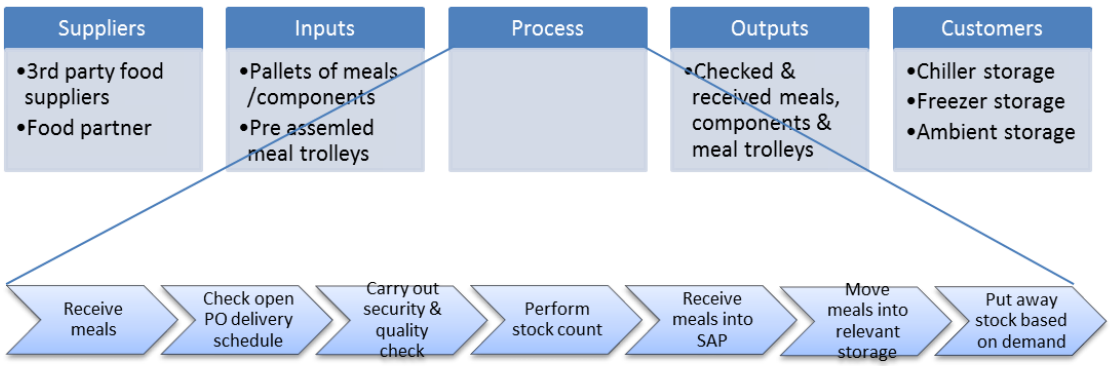
SIPOC Diagram – Food Assembly Process

2. Food Materials Management



SIPOC Diagram – Food MM Process

3. Food Operations - Goods In



SIPOC Diagram – Food Goods In Process

Appendix B – Supply Chain Performance Questionnaires

B.1 Questionnaire for Suitable SCOR Metrics Selection

Following questionnaire has been used to select a set of 55 suitable performance metrics for airline catering supply chain from more than 280 SCOR metrics available in the framework.

Using a scale of 1 to 5 (Criteria 1 = Not at all important, 2 = Slightly important, 3 = Important, 4 = Fairly important, 5 = Very important), please rate the importance of each of the following performance metrics for your airline catering supply chain.

Performance Attribute	SCOR Metric No	Metrics	Process	Score
Reliability	RL.1.1	Perfect Order Fulfillment	Supply Chain	
Reliability	RL.2.1	% of Orders Delivered In Full	Deliver	
Reliability	RL.2.2	Delivery Performance to Customer Commit Date	Deliver	
Reliability	RL.2.3	Documentation Accuracy	Deliver	
Reliability	RL.2.4	Perfect Condition	Deliver	
Reliability	RL.3.19	% Orders/ Lines Received Defect Free	Source	
Reliability	RL.3.21	% Orders/Lines received with correct content	Source	
Reliability	RL.3.23	% Orders/ Lines Received with Correct Shipping Documents	Source	
Reliability	RL.3.20	% Orders/Lines Received On-Time to Demand Requirement	Source	
Reliability	RL.3.24	% Orders/Lines received damage free	Source	
Reliability	RL.3.27	% Schedules Changed within Supplier's Lead Time	Source	
Reliability	RL.3.33	Delivery Item Accuracy	Deliver	
Reliability	RL.3.35	Delivery Quantity Accuracy	Deliver	
Reliability	RL.3.32	Customer Commit Date Achievement Time Customer Receiving	Deliver	
Reliability	RL.3.34	Delivery Location Accuracy	Deliver	
Reliability	RL.3.31	Compliance Documentation Accuracy	Make	
Reliability	RL.3.45	Payment Documentation Accuracy	Deliver	
Reliability	RL.3.49	Schedule Achievement	Make	
Reliability	RL.3.50	Shipping Documentation Accuracy	Deliver	
Reliability	RL.3.12	% of Faultless Installations	Deliver	
Reliability	RL.3.41	Orders Delivered Damage Free Conformance	Deliver	
Reliability	RL.3.42	Orders Delivered Defect Free Conformance	Deliver	
Reliability	RL.3.7	% Item Location Accuracy	Deliver	
Reliability	RL.3.37	Forecast Accuracy	Plan	
Reliability	RL.3.58	Yield	Make	
Responsiveness	RS.1.1	Order Fulfillment Cycle Time	Supply Chain	
Responsiveness	RS.2.1	Source Cycle Time	Source	

Responsiveness	RS.2.2	Make Cycle Time	Make	
Responsiveness	RS.2.3	Deliver Cycle Time	Deliver	
Responsiveness	RS.2.5	Return Cycle Time	Return	
Responsiveness	RS.3.27	Establish Delivery Plans Cycle Time	Plan	
Responsiveness	RS.3.28	Establish Production Plans Cycle Time	Plan	
Responsiveness	RS.3.29	Establish Sourcing Plans Cycle Time	Plan	
Responsiveness	RS.3.35	Identify Sources of Supply Cycle Time	Source	
Responsiveness	RS.3.107	Receive Product Cycle Time	Source	
Responsiveness	RS.3.101	Produce and Test Cycle Time	Make	
Responsiveness	RS.3.142	Package Cycle Time	Make	
Responsiveness	RS.3.16	Build Loads Cycle Time	Deliver	
Responsiveness	RS.3.18	Consolidate Orders Cycle Time	Deliver	
Responsiveness	RS.3.51	Load Product & Generate Shipping Documentation Cycle Time	Deliver	
Responsiveness	RS.3.95	Pack Product Cycle Time	Deliver	
Responsiveness	RS.3.96	Pick Product Cycle Time	Deliver	
Responsiveness	RS.3.102	Receive & Verify Product by Customer Cycle Time	Deliver	
Responsiveness	RS.3.126	Ship Product Cycle Time	Deliver	
Responsiveness	RS.3.20	Current logistics order cycle time	Deliver	
Responsiveness	RS.3.31	External Event Response (average days)	Enable	
Responsiveness	RS.3.47	In-stock %	Deliver	
Responsiveness	RS.3.48	Invoice Cycle Time	Deliver	
Responsiveness	RS.3.100	Process Inquiry & Quote Cycle Time	Deliver	
Responsiveness	RS.3.103	Receive and Verify Product Cycle Time	Deliver	
Responsiveness	RS.3.105	Receive Excess Product Cycle Time	Return	
Responsiveness	RS.3.140	Verify Product Cycle Time	Source	
Agility	AG.1.1	Upside Supply Chain Adaptability	Supply Chain	
Agility	AG.1.2	Downside Supply Chain Adaptability	Supply Chain	
Agility	AG.2.1	Upside Adaptability (Source)	Source	
Agility	AG.2.2	Upside Adaptability (Make)	Make	
Agility	AG.2.3	Upside Adaptability (Deliver)	Deliver	
Agility	AG.2.6	Downside Adaptability (Source)	Source	
Agility	AG.2.7	Downside Adaptability (Make)	Make	
Agility	AG.2.8	Downside Adaptability (Deliver)	Deliver	
Agility	AG.3.1	% of labor used in outbound logistics, not used in direct activity	Deliver	
Agility	AG.3.2	% of labor used in assembly/production, not used in direct activity	Make	
Agility	AG.3.4	Additional Delivery volume	Deliver	
Agility	AG.3.9	Additional source volumes obtained in 30 days	Source	
Agility	AG.3.32	Current Delivery Volume	Deliver	

Agility	AG.3.38	Current Make Volume	Make	
Agility	AG.3.40	Current Purchase Order Cycle Times	Source	
Agility	AG.3.42	Current Source Volume	Source	
Cost	CO.1.1	Total SC Management Cost (TSCMC)	Supply Chain	
Cost	CO.1.2	Cost of Goods Sold (COGS)	Supply Chain	
Cost	CO.2.1	Cost to Plan	Plan	
Cost	CO.2.2	Cost to Source	Source	
Cost	CO.2.3	Cost to Make	Make	
Cost	CO.2.4	Cost to Deliver	Deliver	
Cost	CO.2.5	Cost to Return	Return	
Cost	CO.2.6	Mitigation Cost (Cost to mitigate supply chain)	Enable	
Cost	CO.2.7	Direct Labor Cost	Make	
Cost	CO.2.8	Direct Material Cost	Make	
Cost	CO.2.9	Indirect Cost Related to Production	Make	
Cost	CO.3.7	Cost to Receive Product	Source	
Cost	CO.3.10	Cost to Verify Product	Source	
Cost	CO.3.11	Direct Material Cost	Enable	
Cost	CO.3.12	Indirect Cost Related to Production (Does not include data from COGS)	Enable	
Cost	CO.3.13	Direct Labor Cost (Does not include data from COGS)	Enable	
Cost	CO.3.15	Order Delivery Costs	Deliver	
Asset	AM.1.1	Cash to Cash Cycle Time	Supply Chain	
Asset	AM.2.2	Inventory Days of Supply	Plan	
Asset	AM.3.16	Inventory Days of Supply - Raw Material	Source	
Asset	AM.3.17	Inventory Days of Supply - WIP	Make	
Asset	AM.3.28	Percentage Defective Inventory	Return	
Asset	AM.3.37	Percentage Excess Inventory	Return	
Asset	AM.3.45	Inventory Days of Supply - Finished Goods	Deliver	
Asset	AM.3.9	Capacity Utilization	Enable	
Asset	AM.3.21	Rebuild or recycle rate	Return	
Asset	AM.3.26	Return Rate	Return	

B.2 Questionnaire for Metrics Prioritisation

1. How should the following six performance metrics be prioritised during COVID-19 pandemic for PLAN process in airline catering supply chain? *

	Must have	Should have	Could have	Won't have
Cost to Plan	○	○	○	○
Inventory Days of Supply	○	○	○	○
Establish Delivery Plans Cycle Time	○	○	○	○
Establish Production Plans Cycle Time	○	○	○	○
Establish Sourcing Plans Cycle Time	○	○	○	○
Forecast Accuracy	○	○	○	○

2. How should the following seven performance metrics be prioritised during COVID-19 pandemic for SOURCE process in airline catering supply chain? *

	Must have	Should have	Could have	Won't have
Source Cycle Time	○	○	○	○
Upside Adaptability (Source)	○	○	○	○
Downside Adaptability (Source)	○	○	○	○
Cost to Source	○	○	○	○
% Orders/Lines Received On-Time to Demand Requirement	○	○	○	○

3. How should the following seven performance metrics be prioritised during COVID-19 pandemic for MAKE (ASSEMBLE) process in airline catering supply chain? *

	Must have	Should have	Could have	Won't have
Make Cycle Time	○	○	○	○
Upside Adaptability (Make)	○	○	○	○
Downside Adaptability (Make)	○	○	○	○
Compliance Documentation Accuracy	○	○	○	○
Schedule Achievement	○	○	○	○
Yield	○	○	○	○

4. How should the following fourteen performance metrics be prioritised during COVID-19 pandemic for DELIVER process in airline catering supply chain? *

	Must have	Should have	Could have	Won't have
% of Orders Delivered In Full	○	○	○	○
Documentation Accuracy	○	○	○	○
Perfect Condition	○	○	○	○
Delivery Item Accuracy	○	○	○	○
Delivery Quantity Accuracy	○	○	○	○
Customer Commit Date Achievement Time Customer Receiving	○	○	○	○

5. How should the following four performance metrics be prioritised during COVID-19 pandemic for RETURN process in airline catering supply chain? *

	Must have	Should have	Could have	Won't have
Return Cycle Time	◯	◯	◯	◯
Receive Excess Product Cycle Time	◯	◯	◯	◯
Rebuild or recycle rate	◯	◯	◯	◯
Return Rate	◯	◯	◯	◯

6. How should the following six performance metrics be prioritised during COVID-19 pandemic for ENABLE process in airline catering supply chain? *

	Must have	Should have	Could have	Won't have
External Event Response (average days)	○	○	○	○
Mitigation Cost (Cost to mitigate supply chain)	○	○	○	○
Direct Material Cost	○	○	○	○
Indirect Cost Related to Production/Assembly	○	○	○	○
Direct Labor Cost	○	○	○	○
Capacity Utilization	○	○	○	○

7. What are the challenges brought by COVID-19 pandemic specifically in the context of airline catering supply chain? *

Your answer

8. Would performance metrics help in addressing the challenges highlighted in Question 7? Please explain. *

Your answer

B.3 Questionnaire for Performance Consideration Changes

1. To what extent has the relevance of the following performance attributes in airline catering supply chain changed during COVID-19 pandemic? *

	Very High Decrease	High Decrease	Little Decrease	No Change	Little Increase	High Increase	Very High Increase
Reliability	○	○	○	○	○	○	○
Responsiveness	○	○	○	○	○	○	○
Agility	○	○	○	○	○	○	○
Cost	○	○	○	○	○	○	○
Asset Management Efficiency	○	○	○	○	○	○	○

2. To what extent has the relevance of the following primary management processes in airline catering supply chain changed during COVID-19 pandemic? *

	Very High Decrease	High Decrease	Little Decrease	No Change	Little Increase	High Increase	Very High Increase
Plan	○	○	○	○	○	○	○
Source	○	○	○	○	○	○	○
Make	○	○	○	○	○	○	○
Deliver	○	○	○	○	○	○	○
Return	○	○	○	○	○	○	○
Enable	○	○	○	○	○	○	○

Appendix C – Excel Implementation for Practice Effectiveness Assessment

C.1 Primary Assessment Calculation

Primary Assessment - PE_ij												
	Wijk				Rijk				Wijk X Rijk			
Practice	LV	TFN1	TFN2	TFN3	LV	TFN1	TFN2	TFN3		TFN1	TFN2	TFN3
PE111	H	0.7	0.8	0.9	VG	7	8	9	W x R	4.9	6.4	8.1
PE112	FH	0.5	0.65	0.8	G	5	6.5	8	W x R	2.5	4.23	6.4
PE113	FH	0.5	0.65	0.8	F	3	5	7	W x R	1.5	3.25	5.6
PE11	Sum W	1.70	2.10	2.50	PE11	5.24	6.61	8.04	Sum WxR	8.90	13.88	20.10
PE121	H	0.7	0.8	0.9	VG	7	8	9	W x R	4.9	6.4	8.1
PE122	FH	0.5	0.65	0.8	F	3	5	7	W x R	1.5	3.25	5.6
PE123	M	0.3	0.5	0.7	VG	7	8	9	W x R	2.1	4	6.3
PE12	Sum W	1.50	1.95	2.40	PE12	5.67	7.00	8.33	Sum WxR	8.50	13.65	20.00
PE131	FH	0.5	0.65	0.8	VG	7	8	9	W x R	3.5	5.2	7.2
PE132	M	0.3	0.5	0.7	G	5	6.5	8	W x R	1.5	3.25	5.6
PE133	M	0.3	0.5	0.7	F	3	5	7	W x R	0.9	2.5	4.9
PE13	Sum W	1.10	1.65	2.20	PE13	5.36	6.64	8.05	Sum WxR	5.90	10.95	17.70
PE211	H	0.7	0.8	0.9	G	5	6.5	8	W x R	3.5	5.2	7.2
PE212	FH	0.5	0.65	0.8	G	5	6.5	8	W x R	2.5	4.23	6.4
PE213	FH	0.5	0.65	0.8	F	3	5	7	W x R	1.5	3.25	5.6
PE21	Sum W	1.70	2.10	2.50	PE21	4.41	6.04	7.68	Sum WxR	7.50	12.68	19.20
PE221	M	0.3	0.5	0.7	F	3	5	7	W x R	0.9	2.5	4.9
PE222	H	0.7	0.8	0.9	G	5	6.5	8	W x R	3.5	5.2	7.2
PE223	M	0.3	0.5	0.7	G	5	6.5	8	W x R	1.5	3.25	5.6
PE22	Sum W	1.30	1.80	2.30	PE22	4.54	6.08	7.70	Sum WxR	5.90	10.95	17.70
PE231	M	0.3	0.5	0.7	F	3	5	7	W x R	0.9	2.5	4.9
PE232	H	0.7	0.8	0.9	VG	7	8	9	W x R	4.9	6.4	8.1
PE233	H	0.7	0.8	0.9	VG	7	8	9	W x R	4.9	6.4	8.1
PE23	Sum W	1.70	2.10	2.50	PE23	6.29	7.29	8.44	Sum WxR	10.70	15.30	21.10
PE311	M	0.3	0.5	0.7	F	3	5	7	W x R	0.9	2.5	4.9
PE312	M	0.3	0.5	0.7	G	5	6.5	8	W x R	1.5	3.25	5.6
PE313	FH	0.5	0.65	0.8	G	5	6.5	8	W x R	2.5	4.23	6.4
PE31	Sum W	1.10	1.65	2.20	PE31	4.45	6.05	7.68	Sum WxR	4.90	9.98	16.90
PE321	FL	0.2	0.35	0.5	P	2	3.5	5	W x R	0.4	1.23	2.5
PE322	M	0.3	0.5	0.7	G	5	6.5	8	W x R	1.5	3.25	5.6
PE323	FH	0.5	0.65	0.8	F	3	5	7	W x R	1.5	3.25	5.6
PE32	Sum W	1.00	1.50	2.00	PE32	3.40	5.15	6.85	Sum WxR	3.40	7.73	13.70
PE411	H	0.7	0.8	0.9	VG	7	8	9	W x R	4.9	6.4	8.1
PE412	FH	0.5	0.65	0.8	G	5	6.5	8	W x R	2.5	4.23	6.4
PE413	FH	0.5	0.65	0.8	G	5	6.5	8	W x R	2.5	4.23	6.4
PE41	Sum W	1.70	2.10	2.50	PE41	5.82	7.07	8.36	Sum WxR	9.90	14.85	20.90
PE421	H	0.7	0.8	0.9	G	5	6.5	8	W x R	3.5	5.2	7.2

PE422	FH	0.5	0.65	0.8	F	3	5	7	**W x R**	1.5	3.25	5.6
PE423	FH	0.5	0.65	0.8	G	5	6.5	8	**W x R**	2.5	4.23	6.4
PE42	**Sum W**	**1.70**	**2.10**	**2.50**	PE42	**4.41**	**6.04**	**7.68**	**Sum WxR**	**7.50**	**12.68**	**19.20**
PE431	M	0.3	0.5	0.7	F	3	5	7	**W x R**	0.9	2.5	4.9
PE432	H	0.7	0.8	0.9	G	5	6.5	8	**W x R**	3.5	5.2	7.2
PE433	FH	0.5	0.65	0.8	G	5	6.5	8	**W x R**	2.5	4.23	6.4
PE43	**Sum W**	**1.50**	**1.95**	**2.40**	PE43	**4.60**	**6.12**	**7.71**	**Sum WxR**	**6.90**	**11.93**	**18.50**
PE511	M	0.3	0.5	0.7	F	3	5	7	**W x R**	0.9	2.5	4.9
PE512	H	0.7	0.8	0.9	G	5	6.5	8	**W x R**	3.5	5.2	7.2
PE513	M	0.3	0.5	0.7	F	3	5	7	**W x R**	0.9	2.5	4.9
PE51	**Sum W**	**1.30**	**1.80**	**2.30**	PE51	**4.08**	**5.67**	**7.39**	**Sum WxR**	**5.30**	**10.20**	**17.00**
PE521	M	0.3	0.5	0.7	G	5	6.5	8	**W x R**	1.5	3.25	5.6
PE522	FL	0.2	0.35	0.5	G	5	6.5	8	**W x R**	1	2.28	4
PE523	H	0.7	0.8	0.9	G	5	6.5	8	**W x R**	3.5	5.2	7.2
PE52	**Sum W**	**1.20**	**1.65**	**2.10**	PE52	**5.00**	**6.50**	**8.00**	**Sum WxR**	**6.00**	**10.73**	**16.80**

C.2 Secondary Assessment Calculation

Secondary Assessment - PE_i												
	Wij				**PEij**				**Wij X PEij**			
Function	**LV**	**TFN1**	**TFN2**	**TFN3**	**LV**	**TFN1**	**TFN2**	**TFN3**		**TFN1**	**TFN2**	**TFN3**
PE11	FH	0.5	0.65	0.8	PE11	5.24	6.61	8.04	**W x PEij**	2.62	4.29	6.43
PE12	H	0.7	0.8	0.9	PE12	5.67	7.00	8.33	**W x PEij**	3.97	5.6	7.5
PE13	M	0.3	0.5	0.7	PE13	5.36	6.64	8.05	**W x PEij**	1.61	3.32	5.63
PE1	**Sum W**	**1.50**	**1.95**	**2.40**	PE1	**5.46**	**6.78**	**8.15**	**Sum WxPEij**	**8.19**	**13.21**	**19.56**
PE21	H	0.7	0.8	0.9	PE21	4.41	6.04	7.68	**W x PEij**	3.09	4.83	6.91
PE22	M	0.3	0.5	0.7	PE22	4.54	6.08	7.70	**W x PEij**	1.36	3.04	5.39
PE23	H	0.7	0.8	0.9	PE23	6.29	7.29	8.44	**W x PEij**	4.41	5.83	7.6
PE2	**Sum W**	**1.70**	**2.10**	**2.50**	PE2	**5.21**	**6.52**	**7.96**	**Sum WxPEij**	**8.86**	**13.70**	**19.89**
PE31	M	0.3	0.5	0.7	PE31	4.45	6.05	7.68	**W x PEij**	1.34	3.02	5.38
PE32	FH	0.5	0.65	0.8	PE32	3.40	5.15	6.85	**W x PEij**	1.7	3.35	5.48
PE3	**Sum W**	**0.80**	**1.15**	**1.50**	PE3	**3.80**	**5.54**	**7.24**	**Sum WxPEij**	**3.04**	**6.37**	**10.86**
PE41	FH	0.5	0.65	0.8	PE41	5.82	7.07	8.36	**W x PEij**	2.91	4.6	6.69
PE42	H	0.7	0.8	0.9	PE42	4.41	6.04	7.68	**W x PEij**	3.09	4.83	6.91
PE43	FH	0.5	0.65	0.8	PE43	4.60	6.12	7.71	**W x PEij**	2.3	3.98	6.17
PE4	**Sum W**	**1.70**	**2.10**	**2.50**	PE4	**4.88**	**6.38**	**7.91**	**Sum WxPEij**	**8.30**	**13.40**	**19.77**
PE51	FH	0.5	0.65	0.8	PE51	4.08	5.67	7.39	**W x PEij**	2.04	3.68	5.91
PE52	M	0.3	0.5	0.7	PE52	5.00	6.50	8.00	**W x PEij**	1.5	3.25	5.6
PE5	**Sum W**	**0.80**	**1.15**	**1.50**	PE5	**4.42**	**6.03**	**7.68**	**Sum WxPEij**	**3.54**	**6.93**	**11.51**

C.3 Tertiary Assessment Calculation

Tertiary Assessment - FOPE												
	Wij				PEi				Wij X PEi			
Function	LV	TFN1	TFN2	TFN3	LV	TFN1	TFN2	TFN3		TFN1	TFN2	TFN3
PE1	FH	0.5	0.65	0.8	PE1	5.46	6.78	8.15	W x PEi	2.73	4.40	6.52
PE2	H	0.7	0.8	0.9	PE2	5.21	6.52	7.96	W x PEi	3.65	5.22	7.16
PE3	M	0.3	0.5	0.7	PE3	3.80	5.54	7.24	W x PEi	1.14	2.77	5.07
PE4	H	0.7	0.8	0.9	PE4	4.88	6.38	7.91	W x PEi	3.42	5.10	7.12
PE5	M	0.3	0.5	0.7	PE5	4.42	6.03	7.68	W x PEi	1.33	3.01	5.37
FEI	Sum W	2.50	3.25	4.00	FEI	4.90	6.31	7.81	Sum WxPEi	12.26	20.51	31.24

C.4 Euclidean Distance Calculation

Euclidean Distance - FOPE and OPELi										
OPEL_i				(fFOPE(x) - fOPELi(x))^2				D(FOPE, OPELi)		
Level	TFN1	TFN2	TFN3							
DE	8.5	9.5	10		12.93	10.17	4.80	D(FOPE, DE)	5.28	
VHE	7	8	9		4.39	2.85	1.42	D(FOPE, VHE)	2.94	
HE	5	6.5	8		0.01	0.04	0.04	D(FOPE, HE)	0.28	Highly Effective
AE	3	5	7		3.63	1.72	0.66	D(FOPE, AE)	2.45	
FE	2	3.5	5		8.44	7.90	7.89	D(FOPE, FE)	4.92	
SE	1	2	3		15.24	18.59	23.13	D(FOPE, SE)	7.55	
NE	0	0.5	1.5		24.05	33.77	39.81	D(FOPE, NE)	9.88	

C.5 Fuzzy Performance Importance Index and Ranking Score Calculation

Excerpt of Fuzzy Performance Importance Index																
	Wijk				Rijk				(1, 1, 1) - Wijk			FAII				Ranking Score
Practice	**LV**	**TFN1**	**TFN2**	**TFN3**	**LV**	**TFN1**	**TFN2**	**TFN3**	**TFN1**	**TFN2**	**TFN3**		**TFN1**	**TFN2**	**TFN3**	
PE111	H	0.7	0.8	0.9	VG	7	8	9	0.1	0.2	0.3	**Wi_ijk x R**	0.7	1.6	2.7	1.63
PE112	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35
PE113	FH	0.5	0.65	0.8	F	3	5	7	0.2	0.35	0.5	**Wi_ijk x R**	0.6	1.75	3.5	1.85
PE121	H	0.7	0.8	0.9	VG	7	8	9	0.1	0.2	0.3	**Wi_ijk x R**	0.7	1.6	2.7	1.63
PE122	FH	0.5	0.65	0.8	F	3	5	7	0.2	0.35	0.5	**Wi_ijk x R**	0.6	1.75	3.5	1.85
PE123	M	0.3	0.5	0.7	VG	7	8	9	0.3	0.5	0.7	**Wi_ijk x R**	2.1	4	6.3	4.07
PE131	FH	0.5	0.65	0.8	VG	7	8	9	0.2	0.35	0.5	**Wi_ijk x R**	1.4	2.8	4.5	2.85
PE132	M	0.3	0.5	0.7	G	5	6.5	8	0.3	0.5	0.7	**Wi_ijk x R**	1.5	3.25	5.6	3.35
PE133	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE211	H	0.7	0.8	0.9	G	5	6.5	8	0.1	0.2	0.3	**Wi_ijk x R**	0.5	1.3	2.4	1.35
PE212	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35
PE213	FH	0.5	0.65	0.8	F	3	5	7	0.2	0.35	0.5	**Wi_ijk x R**	0.6	1.75	3.5	1.85
PE221	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE222	H	0.7	0.8	0.9	G	5	6.5	8	0.1	0.2	0.3	**Wi_ijk x R**	0.5	1.3	2.4	1.35
PE223	M	0.3	0.5	0.7	G	5	6.5	8	0.3	0.5	0.7	**Wi_ijk x R**	1.5	3.25	5.6	3.35
PE231	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE232	H	0.7	0.8	0.9	VG	7	8	9	0.1	0.2	0.3	**Wi_ijk x R**	0.7	1.6	2.7	1.63
PE233	H	0.7	0.8	0.9	VG	7	8	9	0.1	0.2	0.3	**Wi_ijk x R**	0.7	1.6	2.7	1.63
PE311	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE312	M	0.3	0.5	0.7	G	5	6.5	8	0.3	0.5	0.7	**Wi_ijk x R**	1.5	3.25	5.6	3.35
PE313	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35
PE321	FL	0.2	0.35	0.5	P	2	3.5	5	0.5	0.65	0.8	**Wi_ijk x R**	1	2.28	4	2.35
PE322	M	0.3	0.5	0.7	G	5	6.5	8	0.3	0.5	0.7	**Wi_ijk x R**	1.5	3.25	5.6	3.35
PE323	FH	0.5	0.65	0.8	F	3	5	7	0.2	0.35	0.5	**Wi_ijk x R**	0.6	1.75	3.5	1.85
PE411	H	0.7	0.8	0.9	VG	7	8	9	0.1	0.2	0.3	**Wi_ijk x R**	0.7	1.6	2.7	1.63
PE412	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35

PE413	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35
PE421	H	0.7	0.8	0.9	G	5	6.5	8	0.1	0.2	0.3	**Wi_ijk x R**	0.5	1.3	2.4	1.35
PE422	FH	0.5	0.65	0.8	F	3	5	7	0.2	0.35	0.5	**Wi_ijk x R**	0.6	1.75	3.5	1.85
PE423	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35
PE431	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE432	H	0.7	0.8	0.9	G	5	6.5	8	0.1	0.2	0.3	**Wi_ijk x R**	0.5	1.3	2.4	1.35
PE433	FH	0.5	0.65	0.8	G	5	6.5	8	0.2	0.35	0.5	**Wi_ijk x R**	1	2.28	4	2.35
PE511	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE512	H	0.7	0.8	0.9	G	5	6.5	8	0.1	0.2	0.3	**Wi_ijk x R**	0.5	1.3	2.4	1.35
PE513	M	0.3	0.5	0.7	F	3	5	7	0.3	0.5	0.7	**Wi_ijk x R**	0.9	2.5	4.9	2.63
PE521	M	0.3	0.5	0.7	G	5	6.5	8	0.3	0.5	0.7	**Wi_ijk x R**	1.5	3.25	5.6	3.35
PE522	FL	0.2	0.35	0.5	G	5	6.5	8	0.5	0.65	0.8	**Wi_ijk x R**	2.5	4.23	6.4	4.30
PE523	H	0.7	0.8	0.9	G	5	6.5	8	0.1	0.2	0.3	**Wi_ijk x R**	0.5	1.3	2.4	1.35