Using Lean Philosophy to Improve Passenger Departure Flow in Abu Dhabi Airport

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Abstract — Lean is an established process improvement philosophy to achieve the operational excellence and the benefits can be more than just improving the process. This is evident as the benefits of Lean are truly exploited in automotive, aerospace and manufacturing sectors. There are numerous implementations of Lean philosophy in service sector such as banking, higher education, software development etc. The main aim of this paper is provide an overview of Lean philosophy and explore the benefits for airport processes. The airport processes are completely different than the manufacturing and other service sectors due to the complex interlinking between different stake holders such as airline regulations, national/international law etc. This paper exemplifies the Lean philosophy by drawing examples form Passenger Departure Process (PDP) in Abu Dhabi International Airport (a major international airport). This paper starts with examining the background to the project and why airports have many characteristic features, which are fundamentally different to the manufacturing environment in which Lean was originally devised. Since its origins, Lean philosophy has been also applied to many service environments. Further, Lean philosophy is introduced and Lean principles and waste is discussed from the PDP perspective. Along this, a brief literature review is presented on the existing process improvement approaches used in the airports. The ultimate aim of the project which it has achieved was to develop a practical methodology of applying Lean principles to the PDP help airline managers and staff eliminates the waste of available resources and so increases the passenger flow through various stages of the process in line with Lean philosophy.

Index Terms — Lean philosophy, Passenger Departure Process, Process Improvement, Passenger Flow, Variability.

1 Introduction

Today, airports form a key part of global infrastructure in an increasingly globalized world. Airports act as a key catalyst for economic development by functioning as an interface through which global networks are moored in a place. Airports operation process improvement is a complex problem due to the complexity of operations and different stake holders involved at different stages of process.

This research paper uses Abu Dhabi International Airport (ADIA) as a case study, which is a major international hub. By 2013, ADIA had a handling capacity of around 12.5 million passengers annually. When the full expansion currently taking place is completed, the airport will have a capacity of 47 million passengers annually, many of whom are transit passengers. Terminal 3 is the home of Abu Dhabi's major carrier, Etihad Airways, one of the world's fastest-growing international airlines. Serving their needs effectively and efficiently while staying sensitive to the needs of passengers is a major strategic aim in this development. Consequently, improvements in this airport are significant to both large and small airports worldwide and this project makes a major contribution to the research undertaken for several years into improving passenger departure flow [1,2,3,4 and 5]because of its use of lean service techniques [6 and 7].

The main aim of PhD research project described in this paper focused on applying the Lean methodology to the PDP in Terminal 3.There were three major objectives of the project: First, to develop a methodology to identify mixed levels of variability using predefined performance metrics identifying operational problems, which influence Lean thinking about the efficient flow of passengers. Second, to identify individual operational cause-and-effect pathways and their ensuing root causes. Third, using simulation modeling to develop a rule-based method to identify root causes and propose Lean solutions to develop preventive solution. This paper describes the approach adopted to achieve the first two major objectives.

This paper is organized as; section 2 provides literature review regarding the passenger departure process (PDP), lean philosophy and existing models of control in departure flow.

2. Literature Review

2.1 The Passenger Departure Process

The PDP consist of a number of completely separate groups of workstation where 'potential passengers' are transformed into 'originating' (approved departing) passengers' through a series of workstation, i.e.;

a. Check-in: Ticket counter and baggage deposit,
b. Ticket screening / Emigration control (border control),
c. Security screening,
d. Departure lounge, and
e. Boarding control.

The principle purposes of check-in are to receive baggage and to give boarding cards to passengers, and to carry out certain duties imposed on airlines by national and international laws [8 and 9]. A typical passenger presents his passport and ticket at check-in [10].

Traditional [In-Airport] check-in is carried out by the Airline. Passengers are typically streamed into 'classes', such as first, business and economy. The Airline checks tickets and identity; receives, weighs and security seals luggage; and checks that passengers have relevant documents to enter the country of destination, the luggage has been packed by the passenger, and luggage does not contain prohibited material [8 and 9]. After baggage is weighed and transferred to handling conveyors, the passenger is given additional documents in the form of a boarding card. Passengers with

special luggage requirements are screened out and sent to other special counters. The type and scope of information required at check-in is destination specific, because each country will impose its own special visa and passenger information requirements [9]. The Airline also checks if Advance Passenger Information (API) has been received on time. Allocation of seating and requests for special dietary needs are handled at check-in [8].

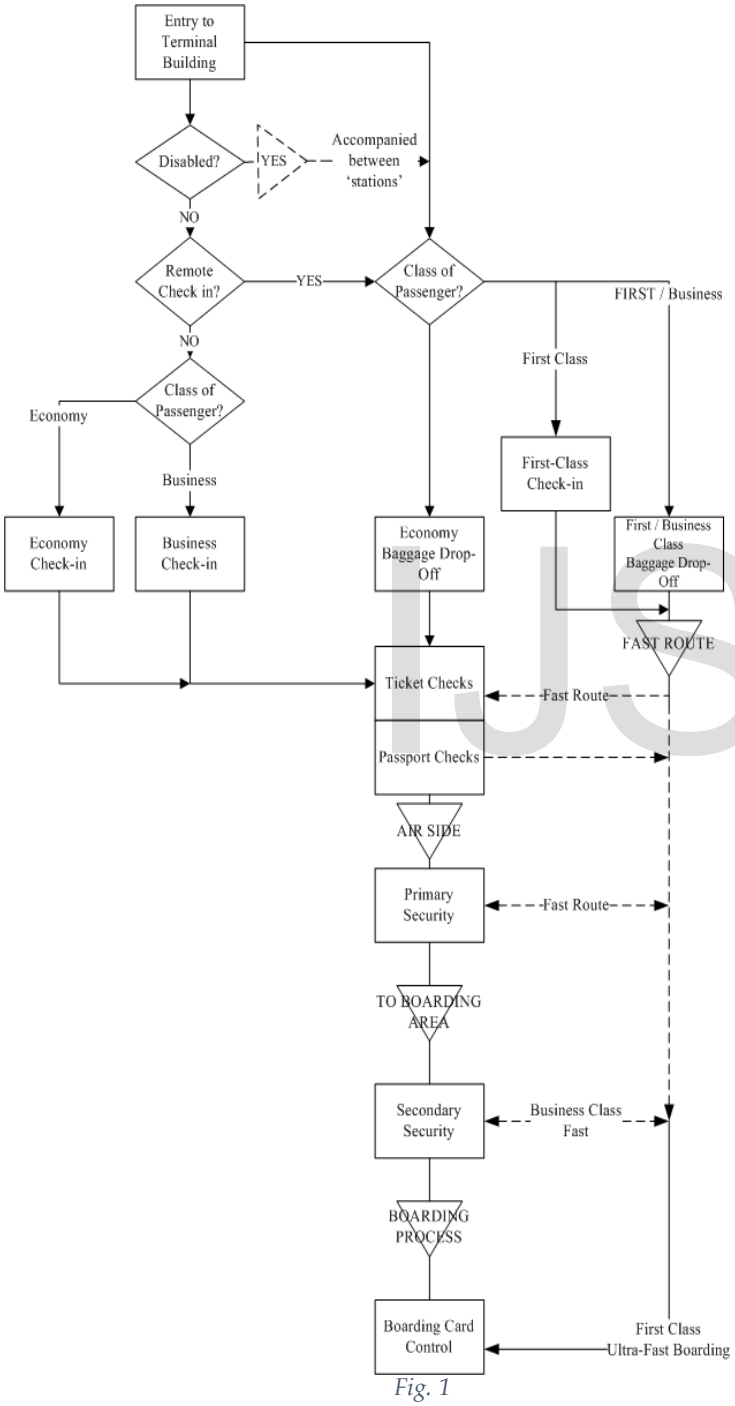

Fig. 1

Schematic Passenger Departure Process

Etihad introduced check-ins which may be carried out remotely over the internet or mobile phones for typical passengers. The Remote Check-in system may also be used to provide API. Passengers complete this process by using automated bag check-in at the airport [8 and 9]. Unusually Etihad provides in-town check-in where passengers may check in luggage at designated centers before travelling to the airport.

Emigration (Passport Control): This group of workstations check that a passenger's passport is valid for the duration of his/her trip or for any period set down by the destination country. Border Control Officers also check that visa, transit and ongoing entry requirements are in order. Only UAE citizens or those holding valid UAE residence visas may use the alternate eGate service [11].

Security: Passengers and their hand luggage are checked in security processing stations. The stations check for compliance with international regulations for items carried, hand luggage and personal possessions are x-ray screened and electronic devices such as laptops and tablets are separately monitored. In the first initiative of its kind in the entire UAE, dedicated facilities exist for security checks for veiled female passengers [12].

Departure Lounge and Boarding Control: Display screens summon passengers to the departure lounge, at a predetermined time before aircraft departure. Shortly afterwards, and a predetermined time before actual airport departure, the boarding control processing station opens to check passengers are available for boarding the aircraft using boarding cards and passports. This group of processing stations also checks for passengers who have checked in but who have not presented themselves at the boarding gate on time [12].

2.2 Lean Philosophy

In the 1980s manufacturing industry sought global competitiveness and found itself needing major changes to operational systems [13]. The answer for some was to adopt Lean philosophy and methods [14 and 13]. Now airports find themselves having to face similar issues. Potentially 'Lean' can provide potential solutions to overcome some of these challenges.

A service environment calls for a quite different Lean approach [7, 15 and 16]. A major reason is to avoid inappropriate "industrialization of service" [17], which would certainly be unacceptable to passengers, airlines and airport operators [4 and 18]. Other Issues special to airports are noted in section 2.3.1.

2.2.1 Lean Principles

Womack and Jones [13] identified five key Lean principles which were expanded by Emiliani[19]as follows:

1. Identify Customers and Specify Value:Only the customer (the passenger) can really define the value of a product or service. All non-value activities may be targeted for removal as 'waste' or muda.
2. Identify and Map the Value Stream: The value stream is "the specific activities required designing, order and providing a specified product [or service]" [16] as seen from the passenger's perspective.

3. Create Flow by Eliminating Waste: Flow is "the progressive achievement of tasks along the value stream" [16] and identifying activities needed for improvement. Contrasts with traditional systems which build up 'inventory' for continuous processing - batch and queue processing (BQP) [19].
4. Respond to Customer Pull: The concept of 'pull' in Lean processes means the customer creates demand which activates the system. This contrasts with BQP which is designed to meet the service operators' own needs driven by demand forecasts and create waste within the system. In PDP Push is created by the 'departure-window' determined in advance relative to scheduled departure time. In PDP, the actual departure time creates the pull in parts of the system, rather than straightforward customer demand.
5. Pursue Perfection: When the first four steps are carried out, all activities become transparent allowing various airport operators to more easily identify and eliminate waste and focus on improving activities which create value.

2.2.2 The Concept of Waste or Muda

There are seven commonly accepted wastes in Lean production systems first developed by TaiichiOhno[14] in Toyota (Table 1):

TABLE 1.
THE CLASSIC SEVEN LEAN WASTES
Derived from Ohno (1988: pp.19-20)

Waste / Description	Application to Airport Processes
1. Overproduction Producing more services than are required at any particular time.	This does not apply to the passenger departure process as only passengers with valid tickets and documents can legally be processed. Arguably, however processing capacity in the form of the excessive provision of manned workstations constitutes overproduction.
2. Waiting Producing queues in a bottleneck.	This occurs at every processing station and in intermediate waiting areas and facilities such as queue check-in process etc.
3. Transport Unnecessary distance travelled between processing stations during work-in-progress.	Although minor modifications are possible, this is largely dictated by the physical layout of the airport, and the need to cater for many different flights and aircraft sizes.
4. Inappropriate Processing Carrying out operations which are wasteful or unnecessary or caused by	Except in exceptional circumstances this does not occur because of the legal requirements about processing
defects, overproduction or excess inventory.	passengers and the use of specific documents with the process.
5. Unnecessary Inventory Maintenance of excessive amounts of raw materials or work-in-progress.	This does not apply to the passenger departure process as only passengers with valid tickets and documents can legally be processed. In any event, it is in airport operators' economic interests to generate excess inventory of passengers within intermediate passenger waiting areas.
6. Unnecessary Motion Additional steps taken by employees and equipment to offset the effects of an inefficient process layout or any other cause due to 1-5 above.	Although minor modifications are possible, this is largely dictated by the physical layout of the airport, and the need to cater for many different flights and aircraft sizes.
7. Defects Products or services which do not conform to the specification or to passenger expectations.	This does not apply to the passenger departure process as because passengers must be dealt with in a legally prescribed way.

The term *muda* is used to define waste is being any activity which absorbs resources and creates no value [16]. Others have since been developed. The most important are shown ibn Table 2.

A detailed analysis applying any of the ten wastes to the departure process was found to be extremely difficult because of the special nature of airport operations. Nevertheless, Lean can still be applied to parts of the PDP by applying a systematic Lean methodology, which after objectives are establishes can identify problems that stand in the way of optimization, rationalize and improve them [20 and 21].

However, given the special constraints created by externally-induced departure delays, different organizations' operators at different work stations, the lack of tangible, unified process control, strict international legal control of airport operations, and economic factors, all of which make airport operations entirely different from processes to which Lean has been previously applied, the challenge was to turn airport departure into a 'total process' rather than a series of loosely-linked individual processes [22]and able to operate in a dynamic, external environment.

TABLE 2
ADDITIONAL WASTES

Waste / Description	Application to Airport Processes
8. Design of appropriate goods and services**[16]** Inappropriate services which do not meet service specifications or customers' needs.	This does not apply to the passenger departure process as because passengers must be dealt with in a legally prescribed way. However, peripheral services, including those used in general buffers where passengers will wait between processing stations are important both to passengers and the Airport Authority.
9. Wastes caused by 'untapped human potential' [23]. Unused potential in service employees.	The potential of individual service employees may be better used though the overriding difficulty in the departure process is that employers differ from one station to the next and so cross-use between stations may be restricted. However, provided peak times for arrival and departure processes differs significantly, therefore, some cross-use of employees may be possible.
10. Failure demand [24] "*Demand caused by a failure to do something or do something right for the customer*" This includes not solving problems, issuing documents customers"Demand caused by a failure to do something or do something right for the customer" This includes not solving problems, issuing documents customers have difficulties with, and so on have difficulties with, and so on	The legal nature of many departure processes means that documents and services must follow a prescribed format. The trend has also been for standardizing or 'industrializing' service. While it essential in manufacturing, standardization actually limits and service organizations' ability to absorb variety and deal with variation. However, reliable computer systems and the availability of various facilities, including for example baggage trolleys may have important effects.

The concept of the value stream is fundamental to understanding Lean. The value stream refers only to specific parts of the process which actually adds value to the service provided [25]. There are three types of activities in the value stream. These are defined as:

1. "Value-added: those activities that unambiguously create value.
2. Type I Muda: activities that create no value but are unavoidable such as regulatory requirements, current technologies and existing assets.
3. Type II Muda: activities that create no value and are immediately avoidable" [16].

2.2.3 Passenger Departure Flow Process Mapping

The term 'process mapping' describes processes in terms of how the activities within the process and how they relate to each other [26]. Each process represents different types of activity take place during the process and show the flow of people or information through the process [26]. The rationale behind mapping is to help identify waste in individual value streams. Once identified, removal or reduction of waste within the process can begin. Each step in the departure process was categorized in terms of activities types such as operations, inspection, transport and storage. A series of process maps was produced for the entire Terminal 3 though because of the constraints of security and available space in this paper they have not been reproduced here. Nevertheless, process mapping give a full picture of all activities taken place with departure process.

Mapping also creates a problem-solving framework [25]. While this analysis process was aimed at manufacturing operations, a similar process was used to map the departure flow process with adaptation, especially for Class I Muda.

2.3 Existing Models of Control in Departure Flow

2.3.1 Task Division of Process Control and Management

A defining characteristic of the PDP is its dissimilarity to manufacturing or service processes to which Lean has previously been applied. Each group of processing stations is under different control [9]. The changing locus of control occurs throughout the PDP because of the special nature of airport terminals. Kellerman [27] describes an airport terminal as an "environment of authorities". The environment is different when viewed from the perspective of various involved parties such as airport management bodies, regulators, governments, commercial operators and suppliers as well as passengers. The effects of terrorism and organized crime have made the airport "the most authoritarian facility designed for the use of free citizens by the wider base, amount, domain and scope of authority powers" [27].

Most airports have intermediate facilities. Intermediate facilities fulfill important functions which grew from the inherent uncertainty of aircraft arrival and departure times for originating and transfer passengers. Shopping, especially duty-free shopping, restaurants and cafes and other activities were found to be not only methods of occupying passengers and reducing passengers' stress [28] but as valuable revenue-earners for the airport [29]. The income that franchisees provide for airport is so valuable it is incorporated into airport economic and financial models without which many airports simply could not operate [30]. Thus it is in an airport's interest to encourage passengers to stay as long as possible in

intermediate facilities on both landside and airside [28]. This creates problems when considering Lean improvements because the focus is not taking passengers as quickly as possible through the PDP, but rather reducing 'necessary' time at processing stations and freeing passenger time to use intermediate facilities [28].

From this perspective, the PDP resembles a supply chain [26] more than a simple end-to-end manufacturing or service process. In this model, various operating entities become 'partners' in the process. In the PDP operators cooperate to a limited extent over, which flows and linkages allowing joint accomplishment of the departure process. Ultimately, the Airport Authority acts as a coordinator which can request or order particular actions by overall workstation operators. The Airport Authority is also the main deliverer of customer relations management [26] which, as well as providing customer service, enforcing standardized processes and taking an overall view of airport operations.

2.3.2 Special Features of Queuing in the Departure Process

Passengers moving through the PDP may experience queuing and delay, often because of various capacity and resource constraints [4]. Such constraints are associated with various factors. These include cumulative peaks in demand because of daily, weekly, monthly or seasonal traffic flow distributions [10 and 31]; increased security; shorter connection time for the transfer passengers; or the need to better use assets [32]. Other causes include limited equipment or human agents [10, 32 and 33]. Passenger flow may also be affected by the size of aircraft or the particular destination [1 and 4] or the earliness distribution of passengers arriving at any of the processing stations [31 and 33]. Taken together, these potentially create considerable variability.

Only some of this variability can be predicted because of the effect of external influences on departing aircraft. This makes any attempt to smooth passenger flow through the departure process increasingly difficult especially if constraints are imposed by a fixed physical layout or the process depends on a single workstation.

2.3.3 Existing Means of Analyzing the Departure Process

Literature relating to queue management and process flow is limited especially in relation to PDP flow [34]. This led to diverse methods of queuing management including deliberate over-provision of processing stations; ad hoc methods of opening service counters and processing stations; use of simulation to develop more accurate models of bottlenecks and flow; to rule-based algorithms. The most common algorithm models are based on Markov or semi-Markov statistical models which use probability theory to create a stochastic process capable of predicting flow [34, 35 and 36].
Bittel, et al. [8] and Kaffa-Jackou, et al. [37] both used statistics-based analytical models. Bittel et al. [8] used them when evaluating the impact of Aviation Security Policies on passengers and airlines. Kaffa-Jackou, et al. [37] focused on internal security operations to better enable efficient allocation of equipment and work teams and minimize the possibility of dangerous situations.This was achieved while simultaneously maintaining minimum levels of service quality. Majeske and Lauer [2] developed two Bayesian decision models to analyze security workstations; a single stage model to aid the original computer-assisted passenger pre-screening system and an improved two-stage model which used pre-screening techniques to filter out potentially high-risk passengers. This significantly reduced bottlenecks at security workstations.

3. Research Methods

It was decided to adopt a partly objectivist, partly realist research philosophy [38] because of overwhelming influence of external factors which affected Terminal 3's environment. Taking both epistemology and ontology into account suggested a 'functionalist' research paradigm [39]needs to be adopted. This paradigm assumes that 'objectivist' and 'regulatory' dimensions were adopted. This research thus adopted a mixed-methods research methodology which involved collecting both qualitative and quantitative data. The analysis procedures allowed numerical data to be questioned by triangulation with qualitative information [38].

Existing instruments already exist for collection of both quantitative and qualitative data. The international Airport Service Quality organization developed a performance benchmarking program administered by Airports Council International. The latter, which regularly measures quality in all airports worldwide has produced a detailed Airports Service Quality Performance (ASQP) methodology accompanied by a survey manual which airport staff are accustomed to seeing regularly applied. Since its launch the ASQP methodology has been tested in airports worldwide. Thus it made sense to use suitable parts of ASQP to collect data using a program which runs on Personal Digital Assistant. There was considerable concern for the need for extreme caution in handling these data for security reasons. For secure handling of data, the ASQP program was linked directly to a secure computer storage facility heavily shielded from tampering. Results obtained were validated using simulation which will be described in a subsequent paper to this one.

4. Contribution of the Work and Future Work

The main focus of this paper is to provide a comprehensive literature review about the airport operations, especially focusing on the passenger departure process in order to highlight the different levels of variability that can affect the PDP operations. Along this, paper here exemplifies the Lean philosophy and relates it to the airport operations, where section 2.2.1 and 2.2.2 exemplifies the value and waste from the PDP perspective. In the nutshell, this paper illustrates the fundamental aspects of PDP process from Lean perspective and paves the way to develop an integrated methodology to improve the PDP. This aligns with the other objectives of research project, for instance, process mapping is translated in to the discrete event simulation model, preliminary analysis of simulation results in order to understand the affest of variability and development of logic control based on preliminary analysis in order to improve the PDP process.

Ultimately, the proposed methodology is envisaged to help moderately-trained airline managers and staff to make more informed decisions in order to reduce the PDP waste. Instead, using the principals of these rules, simple numerical parameters based on experience allow staff or managers to amend parameters to suit changing circumstances. Therefore, future work will build on the fundamental PDP knowledge presented in this paper in order to exemplify the benefits of proposed methodology.

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