Applying just-in-time principles in the delivery and management of airport terminal buildings

Low Sui Pheng
Department of Building, National University of Singapore, Singapore
Faisal Manzoor Arain
Southern Alberta Institute of Technology (SAIT), Calgary, Canada, and
Jolene Wong Yan Fang
Department of Building, National University of Singapore, Singapore

Abstract

Purpose – This study aims to examine how the just-in-time (JIT) principles can be adopted for the air travel industry with specific emphasis on the management and operations of terminal buildings in airports.

Design/methodology/approach – Three methods were adopted for the empirical part of this study. These included the observational walk-through, interviews and survey questionnaires conducted in the Changi International Airport in Singapore. The evaluation for JIT application, as part of a larger study, includes the points of arrival and departure, the check-in hall, immigration area, transit mall, gate lounges, food and beverage outlets, retail shops as well as other management initiatives that strive for continuous improvement. This paper focuses only on the check-in hall.

Findings – Japanese businesses have been able to compete successfully in the world market in recent decades because of their total dedication to quality and productivity issues. This has been made possible in part by the guiding principles of the JIT concept which many Japanese businesses subscribed to. The JIT principles include waste elimination, pull production system, uninterrupted work flow, total quality control, top management commitment, employee involvement, long term working relationships with suppliers and continuous improvement. The JIT concept was specifically examined in this study in the context of the Changi International Airport through its planning processes and existing operations. The study was able to highlight the strengths as well as areas for potential improvements in the airport through the application of the seven JIT principles.

Practical implications – Beyond Japanese businesses, the JIT concept was also found to have benefited organizations in a wide range of industries including those relating to the built environment. The study covers major processes and procedures typical of the spatial management and operations of major airport terminal buildings which holds promising lessons for airport management worldwide.

Originality/value – The analysis shows significant potential in applying JIT principles for managing airport operations within the confines of the physical airport terminal buildings. It recommends that designers, project managers and asset managers should progress beyond the traditional "design follows functions" approach to adopt the more integrative "design follows JIT-driven functions" approach.

Keywords Just-in-time, Built environment, Management, Airports, Design and development, Singapore

Paper type Research paper

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Introduction

It was said that elements of the just-in-time (JIT) philosophy were first used in the Ford Motor Company by Mr Henry Ford, but only made its mark prominently when

Much of the analysis presented in the study would not have been possible without the valuable feedback, comments, suggestions, recommendations and assistance provided by the professional airport managers and airport staff in the fieldwork conducted in Singapore.

Mr Taiichi Ohno, then the Executive Vice-President of the Toyota Motor Corporation, adopted it successfully as part of the Toyota Production System in the early 1950s (Ansari and Modarress, 1990). The JIT concept was thereafter widely recognized following its phenomenal implementation in the Toyota Motor Corporation, which transformed the corporation into a successful organization.

The JIT concept is a continuous process of striving to minimize elements in manufacturing systems that restrain productivity. When successfully implemented, the JIT concept will reap the following benefits: reduced inventory levels, improved quality levels, reduced scrap and rework rates, reduced manufacturing lead times, improved customer service levels, improved employee morale and overall improvement of productivity and profitability. The seven fundamental JIT principles are shown in Figure 1.

The JIT concept has been shown to help construction firms to increase their productivity in various aspects (Low and Chan, 1996; Low and Mok, 1999; Low and Wu, 2005). However, one little known aspect relates to an understanding of how the JIT concept can be used to evaluate the efficiency of a completed construction site layout (Low and Mok, 1999), as well as that of a completed industrial building (Low and Show, 2008).

The JIT concept has been proven time and again to be successful for firms based in Japan. However, there was minimal publicity of this concept outside of Japan until Kawasaki in Lincoln, Nebraska in the USA successfully adopted the concept (Schroeder, 1989). Following the Kawasaki's experience in the USA, other firms such as Boeing, Southwest Airlines, General Electric, Hewlett-Packard and IBM have also since then took into account the JIT concept in their manufacturing processes (Low and Chan, 1997).

In every business, the most important focus is on how the end users feel about the final products or services experienced. Since their opinions are highly valued, customer involvement is necessary in product design, development and delivery (Bowen and

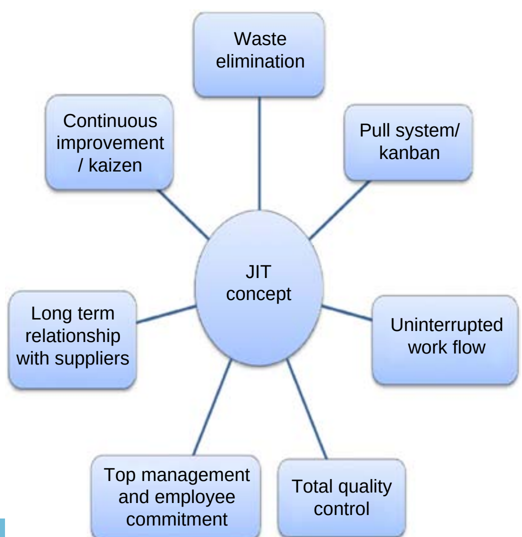


Figure 1.
Seven fundamental principles of the just-in-time (JIT) concept

Youngdahl, 1998). Hence, if possible, customers should be contacted early for their views for improvements in the planning stage in order to achieve good quality and ultimate satisfaction.

The first objective of this paper, as part of a larger study conducted at the National University of Singapore, is to examine how the JIT principles can be applied to further develop and/or enhance the design of the airport terminals. The second objective is to review the application of the JIT principles to each airport feature. The third objective is to propose recommendations for the appropriate JIT principles to be adopted, especially with respect to those airport features with currently low applicability. Airport planners and managers can then consider taking these recommendations into account to plan, develop and construct future airports or for the rejuvenation and re-development of existing airport terminals.

In considering the total life cycle of a building, it is worthwhile for the airport planners and managers, as well as designers, project managers and asset managers to consider progressing beyond the traditional "design follows functions" approach to the more integrative "design follows JIT-driven functions" approach, which this paper seeks to surface.

Three methods were adopted for the empirical part of this study. These included the observational walk-through, interviews and survey questionnaires with professional airport managers and airport employees.

The evaluation for JIT applications, as part of the above-mentioned larger study, included the following areas in the airport:

- points of arrival and departure;
- check-in hall;
- immigration area;
- transit mall;
- gate lounges;
- food and beverage outlets;
- retail shops; and
- other management initiatives that strive for continuous improvement.

All these areas were examined in 2009 as part of the above-mentioned larger study. However, because of space constraint, this paper will only present the findings relating to the check-in hall in the airport terminal building. The check-in hall was chosen for presentation in this paper because this area is most visible and readily accessible to members of the public, in the first instance, in the airport terminal building.

Airport management

One apparent difference between the manufacturing sector and the airport context is the complexity of airport operations in the latter. In most major airports, the working procedures are more uncertain due to the complex flow of users at different times of the day. This is in sharp contrast with the standardized working procedures found in most factories. Although there are standard procedures for passengers to follow in the airport, how the operations are carried out would depend on the passengers themselves. Passengers cannot be controlled in terms of their preferences, priorities, walking speed, as well as their baggage and check-in methods. This is quite unlike the manufacturing sector where companies have stringent control over workers' efficiency and quality management systems.

Conversely, excellent service quality is of utmost importance to airport management. This means some of the JIT principles have to be modified appropriately to cater to the way in which the airport works. One such instance is that there is always a constant need to keep inventories such as the trolleys for travelers to put their baggage. There appears to be no definitive way to anticipate the exact number of trolleys that passengers will use at any one time. One solution is for the airport management to provide for more trolleys rather than less to maintain a good level of airport service. Besides keeping inventories, there are many other areas that the JIT concept can help to provide significant contributions for the airport to achieve excellent service quality. The JIT concept will therefore be evaluated within the context of the fundamental problems that may impede the progress of an airport in terms of efficiency, productivity and profitability. This will also provide a first account of how the JIT concept can be applied to assess the degree of service quality in airport operations, as well as provide a platform for airport management to reflect and strive toward continuous improvement.

The objective of modifying the JIT principles for airport management will be incomplete if only the JIT's side of the story is examined. To provide a more complete picture, similar studies are needed to provide a better perspective of how the JIT principles can be relevant in the airport-operating environment. For this purpose, the Changi International Airport in Singapore, being one of the leading and most advanced major airports in the world was identified as a suitable airport for further evaluation of the airport-operating environment.

The Changi International Airport has a long history dating back to when Terminal 1 first commenced operations. There are currently three terminals operating in the Changi International Airport. Since its opening in 1981, the airport has made its mark in the aviation industry as a benchmark for service quality excellence, winning over 340 awards since its opening and with 19 Best Airport awards won in 2007 alone (Changi Airport, 2008). At the time of this study, the international accolades for Changi International Airport continued to flow in worldwide. Being recognized repeatedly as one of the "Best Airports" globally for its high efficiency, it is worthwhile to examine what Changi International Airport has done right strategically to improve continuously for it to maintain its world renowned reputation. This study therefore aims to examine the planning and operating processes of Terminal 2 and Terminal 3 in the Changi International Airport through the use of the JIT principles.

Changi International Airport Terminal 2 started operations in 1990, followed by an extension project in 1996. Deploying a linear configuration that runs parallel to the runways, it is located adjacent to Terminal 1 toward the south. Terminal 2 also heralded in the opening of the original sky-train system that links the two terminals via the landside (Flight Memory, 2008). It occupies an area of 358,000 m^2 and is able to handle 23 million passengers every year. Terminal 1 was built with the planning concept of functionality. As aviation activities increased over the years, planning concerns were shifted toward providing passengers with enhanced quality in terminal design and improvements in ambience, together with technological advancements.

Changi International Airport Terminal 3 was opened in 2008. The S$1.75 billion terminal, comprising of a space area of 380,000 m^2, is located directly opposite Terminal 2. It is the largest among the three terminals. The terminal itself has seven floors with three levels of basements and four levels above ground. Various services and amenities such as necessities outlets, retail shops, as well as food and beverage outlets are provided for employees, passengers and users. All in all, Terminal 3 focuses on four design principles that are underpinned by clarity, natural lighting, external views and maintainability to derive the best value for its users.

While it appears that the Changi International Airport has already excelled in many ways, where operational and procedural management is concerned, it is postulated that the airport should not rest on its laurels. Instead, like many great organizations and companies worldwide, the airport should consistently strive for continuous improvements in all its endeavors, large and small, to further enhance the customer experience (Balakrishnan, 2003). It is with this in mind that this study posits that continuous improvements for the Changi International Airport can come about by benchmarking its existing operations and procedures with the JIT principles presented below.

Research methodology

The case study approach forms the basis for the research design. A case study, namely the Changi International Airport in this paper, is an intensive study of a single group, incident or community (Kumar, 2005). As mentioned earlier, three methods were adopted for the empirical part of this study; namely the observational walk-through, interviews and survey questionnaires. The reasons for their use are discussed briefly below.

(1) Observational walk-through

The observational walk-through method provided the research team with the opportunity for site visits to better understand how the airport operates as well as to observe firsthand, how the JIT principles may be of relevance. The first visit was a walk-through in Terminal 2 and Terminal 3, led and accompanied by senior airport personnel in July 2008. In the second site visit, which was also conducted in July 2008, the Budget Terminal and its operations were examined. During the third visit in August 2008, a briefing was also conducted for the research team that centered mainly on the airside area that included the baggage handling system (BHS) and airfields in both Terminal 2 and Terminal 3.

(2) Interviews

Interviews are important to obtain firsthand anecdotal information from respondents with the necessary experience in the chosen field of study (Kumar, 2005). Apart from the site visits, interviews were also significant for this study in drawing out the experiential-based opinions relating to the applicability of JIT principles in the airport. The interviews were conducted in July and August 2008 with two experienced managers from the relevant airport authorities. The first interview focussed mainly on the planning issues relating to terminal facilities such as the check-in area, immigration, security system, gate holding rooms, etc. The second interview session focussed on design aspects that were not covered previously.

(3) Questionnaire survey

Quite apart from the site visits and interviews, the questionnaire survey offered yet another research tool to reach out to a larger number of people who can provide inputs to the subject matter of the study (Kumar, 2005). Two organizations that were directly responsible for managing and overseeing the airport participated in the surveys. The respondents were mainly managers and senior managers in the airport. Most of them have had at least two years of experience in the aviation industry. A questionnaire was formulated and pilot tested before the full-scale survey being carried out. A total of 51 questionnaires were distributed to potential respondents with experience in airport management and operations. A total of 33 questionnaires were completed and returned. The respondents were required to rate (on a scale of 1-5, with 1 being the least applicable and 5 being the most applicable) the applicability of each of the JIT principles to each of the airport elements. Several statistical analyses were used to examine the questionnaire results as part of the larger study. However, for reason of space, only the analysis anchored on the statistical mean is presented here. If the average rating is greater than three, it can be said that the respondents as a whole are more receptive to the principle being applicable to the airport features and vice versa.

Applications of JIT principles

There are seven principles under the umbrella of the JIT concept. These are: elimination of waste, kanban/pull system, uninterrupted work flow, total quality control, top management commitment and employee involvement, supplier relations and continuous improvement.

The application of JIT principles is not restricted only to the construction or manufacturing stage. It can also be extended to the planning stage in the layout of a building (Low and Show, 2008). However, certain JIT principles may need to be redefined for application, depending on the functional operations and needs of the business in the building. The seven JIT principles presented earlier will be examined in the context of the Changi International Airport.

Principle 1: elimination of waste in the airport

Elimination of waste refers to eliminating all unnecessary stocks and to decrease or minimize wastage (Low and Mok, 1999). In the context of the airport terminal, it can be referred to the minimizing of waste as applied to the airport layout and its work processes. The work processes are the repetitive and routine procedures required to perform passenger check-ins, to seek clearance through immigration, to board the planes and so on. The seven causes of waste under the elimination of waste principle are evaluated below. However, it should be noted at this stage that not all of these may be relevant in the context of an airport.

Waste from over-production. Waste from over-production in manufacturing would typically refer to the excess quantities of the manufactured products. In this context, demand can be quantified quite easily. If the supply from the production exceeds the amount of demand, there is over-production. But this may not be identifiable so readily in the airport context as the object to be quantified is primarily service, which can be subjective with no absolute mode for calculation. For example, at times when there are low frequencies of flights, there would be fewer people using the lifts. When there are more flights, there may be many more people who may want to use the lifts at any one time. Sometimes, people may prefer to use the escalators instead of the lifts. It appears difficult to predict the actual or estimated amount of production that should be supplied. Consequently, the nature of this waste may seem difficult to encapsulate and appears therefore irrelevant in the context of the airport.

Inventory waste. Similarly, inventory waste does not seem to be applicable in the context of the airport. This is because inventory storage is required to maintain quality service standards for passengers arising from the demand uncertainties in the airport.

Waste from product defects. Unlike manufacturing, there are predominately no physical products associated with an airport building *per se* where quality service provision is concerned. The provision of excellent service for the purpose of serving the passengers appears to be the key emphasis of an airport. Even if service can be termed as a product, service itself can be subjective and can differ from passenger to passenger. Hence, it appears difficult to judge offhand if the service provided is considered "defective." Consequently, waste from product defects does not seem to be relevant where applicability in the airport context is concerned.

Transportation waste and processing waste. The airport does not operate like a factory where components form part and parcel of the final products. Hence transportation waste and processing waste arising from the physical production process do not appear to be of concern to airport management in terms of the spatial layout design within the airport terminals.

Waste of waiting time. Waste of waiting time refers to the overall waiting time experienced by the passengers. This is related to the number of mandatory work processes that each passenger has to go through. The waiting time can be quantified during peak and off-peak periods. There may be other factors that will affect the duration of the waiting time. Typically, a passenger is observed and/or expected to wait longer during the peak period. The concern should therefore be focussed on the methods of how to minimize the waiting time so as to achieve efficiency that translates to good quality service.

Waste of motion. In achieving good spatial layout design, constant efforts are needed to plan the airport layout and/or architecture to accommodate the mandatory work processes in a more efficient manner. For example, airport gates are commonly situated away from the immigration gates so as to prevent congestion. There are also other creative ways where the airport has deployed in managing such waste. In many cases, the use of appropriate technology has been seen as a good tool for implementation to minimize and/or eliminate waste of motion and unnecessary efforts.

Waste of space and energy. Waste of space and waste of energy are two relevant causes of waste in the context of the airport. Waste of space refers to any wastage of space that occurred as a result of poor design in the spatial layout. This can be avoided if the space is planned properly and flexibility is exercised for the space to be fully utilized.

Waste of energy refers to any form of energy waste. This predominately comes from mechanical and electrical (M&E) services that include lighting, air-conditioning, lifts, escalators and others. Given that the present emphasis in construction is on sustainability, this form of waste will be of importance to the management of Changi International Airport. Some possible ways to eliminate this waste can include using energy-saving devices or to position the M&E services near to the occupants. For example, placing the air-conditioning diffusers nearer to the occupants at ground level in an airport terminal would help to save more money than to supply cool air from a high ceiling level.

Principle 2: kanban or pull system in the airport

The "kanban" is the Japanese term for a card that is used to signal the delivery of materials from one workstation to the next workstation on demand. Some modifications need to be made in order to fit this principle appropriately within the airport context. Since the work flow in the airport is not about physical construction or production process, the workstations can be referred to as procedures that a passenger has to go through from one station to the next. Hence, the kanban or pull system can be defined to mean attracting or "pulling" a process or people over to the next station to achieve benefits that focus on either the needs of the airport or those of the customers'. One useful example is the directional signage that is positioned at strategic locations to guide the passengers. This is especially crucial when there are choices to various locations, which a passenger can head to next in the airport terminal.

The kanban system can also be defined as a principle that provides for a service when there is a demand for it. The service does not need to be produced and stored on the spot. But it will be supplied when the need arises. Some airport planning uses the push system and produce more than what is needed in order to maintain quality standards. This is undesirable. Unlike manufacturing, the demand for certain things (especially services) cannot be predicted that readily. One such case relates to the trolleys used in the airport terminal. It appears difficult to determine whether a passenger will pick up a trolley to use, as this action is dependent on the passenger's preference and the amount of baggage carried. To provide good quality service, excess trolleys have to be provided because the airport management cannot have less than what is necessary for the passengers.

Principle 3: uninterrupted work flow in the airport

In the context of an airport, the focussed factory concept can be related to the grouping of a single family of items and/or processes arranged together in the layout of an airport terminal. On the other hand, the group technology concept can be described as the grouping of family of similar parts or components in a continuous layout that leads from one passenger procedure to another. For example, the airport displays the group technology technique of providing a layout that leads passengers from the check-in area to the immigration area (Low and Mok, 1999; Low and Chan, 1997).

For design of simplification and automation, the airport terminal can make use of this technique to "install" the easiest possible route for any passenger to go through without difficulty and without the help of signage. In addition, automation had proven to be strategically useful in the Changi International Airport.

The technique of reduction of process set-up time does not appear to be that relevant in the airport. This is because airport processes are not concerned with the manufacturing of products, which would involve the tooling of machines. As for the Total Preventive Maintenance program, maintenance issues are outsourced to the operators and suppliers. Penalties can be imposed if breakdowns happen to the People Mover System (PMS) and other equipment. This imposition is necessary because the service provided by these machinery and equipment is highly valued in the airport.

Principle 4: total quality control in the airport

In the airport context, quality control means that the responsibility to ensure excellent work quality is delegated to all the employees. The employees play an important part in exploring ways, through their brainstorming sessions and discussions, to achieve excellent work standards through quality control circles. Quality in the airport means that quality is placed under control with careful planning and design of the spatial layout for each of the passenger procedures. This design can affect the work processes in terms of efficiency and the level of comfort for the passengers. When the airport management had taken steps to ensure quality in the work processes or spatial arrangement, quality control has to a large extent been exercised.

Principle 5: top management commitment and employee involvement in the airport
To derive the most benefits from a good spatial layout in the airport, employees at all levels must be involved. Airport leaders and top management must believe in consulting widely and appreciate the need to work closely together with employees and customers to ensure the best possible operating structure for the airport (Ministry of Transport, 2008). Feedback and suggestions are to be obtained from both the employees and the airport users. The employees involved must cut across all hierarchical levels that range from those in airport management, operations and especially so for those who are at the frontline in the daily operations. Similarly, in certain areas pertaining to planning and development issues, employees should be encouraged to be actively involved and engaged.

In addition, in the case of the Changi International Airport, airport-wide campaigns and training programs have been conducted to train and motivate frontline staff to provide good customer service. The training is provided by the airport management to continuously develop the skills and flexibility of the airport employees.

Principle 6: supplier relations in the airport
The service excellence in an airport is dependent on the quality provided by the suppliers. Any external party who provides the airport with a service can be considered as a supplier. These suppliers include the maintenance contractor, PMS provider, cab operators and so on. The JIT concept requires the suppliers to provide consistency and high quality in their performance or service. In addition, to maintain good airport quality, the suppliers should be producing quality products in the right quantities at the right time to suit the customer needs. If the suppliers do not perform up to the standards required, penalties can be imposed on them.

Principle 7: continuous improvement in the airport
This principle can be used to improve productivity through the layout of the terminal. In the context of the Changi International Airport, lessons learnt from Terminal 2 were examined and used for improvements in Terminal 3, where appropriate. In addition, areas that have performed well should extend its applicability and continuity to subsequent terminals. One important reason why the Changi International Airport has been able to maintain its status as a world-class airport for many years is that steps have always been taken to strive for continuous improvements.

Check-in hall as the focus area

There are many areas in a large international airport that cannot be covered in this paper because of the words constraint. The check-in hall forms the focus of this study because this is the area where the passengers first come into contact with and must necessarily experience when in the airport terminal building. The acceptance by the airlines of passengers and their checked baggage take place in the check-in hall, which consists of the check-in counters with appropriate baggage conveyance facilities. The layout of the check-in hall is largely influenced by the check-in concept planned by the airport authorities. It is therefore essential that the airlines or their handling agents are consulted early in the terminal design and planning process. This will ensure optimal operational effectiveness in the allocation of check-in counters to the various airlines and their handling agents (IATA, 2004). The air-conditioning system, check-in counters, baggage system and other features in the check-in hall will be discussed relative to the applicability of the appropriate JIT principles.

Pinnacles – signage with air-conditioning diffusers

The air-conditioning units are well hidden at the check-in hall in the terminal building. These units have been intelligently integrated with the check-in counters. Each of the counter signage is known as a pinnacle (see Figure 2). The pinnacle is the structure which displays the luminous check-in gate number that the passengers look out for when they check-in. The structure has dual functions.

First, the pinnacle informs the passengers from afar where they are supposed to go for their check-ins. The tall and luminous structure gives a distinctive view of the gate number (e.g. number 11 in Plate 1) at one glance. There is space saving because the air-conditioning system is also built into this architectural feature.

Second, each pinnacle incorporates the air-conditioning diffusers. These air conditioning units are also strategically placed throughout the terminal building to provide a consistently cool temperature at the occupancy level. Cold air that is supplied at a high ceiling level will waste energy in cooling large areas of unoccupied space. This new displacement air-conditioning system is used in the departure hall of Terminal 3 to cool the occupied area at about 5 m above the floor level where most of the occupants can be found. Hence, the pinnacles help to eliminate energy waste that is reflective of the JIT concept.

At the same time, from the aesthetical point of view, having the conventional air-conditioning system with ducts and vents in the ceiling would ruin the architectural beauty of the roof (Lim, 2008). These design principles appear to have complemented each other very well and added tremendous benefits to the Changi International Airport.

Flight information display system (FIDS)

Situated at the entrance of the check-in hall are the FIDS. Previously, the FIDS in Terminal 2 consisted of a big board (see Plate 2) located in a centralized position with six door gates sharing two such systems. This often caused human congestion at these

Plate 1.
A typical pinnacle in Terminal 3

Plate 2.
Flight information display system in Terminal 2

areas. Continuous improvements appear to have been implemented since then in Terminal 3 with the FIDS screens (see Plate 3) situated along the passenger route to the check-in hall with two door gates sharing one system. Congestion is now no longer an issue. Through such continuous improvements, uninterrupted work flow has also been achieved since passengers no longer have to walk to the centralized FIDS board before proceeding to the check-in counters. There is overlapping of two JIT principles relating to continuous improvement and uninterrupted work flow, resulting in better outcome for the airport users.

Check-in counters and layout

Terminal 3 uses the island type of check-in layout. This type of layout means each island, where the axis is oriented parallel to the flow of passengers through the terminal concourse, consists of about 10-20 individual check-in counters on each side (IATA, 2004).

This facilitates smooth passenger flow. The location of the airlines in this layout indicates that the focussed factory technique under the JIT principle of uninterrupted work flow is deployed because the airline counters are positioned together at the check-in hall.

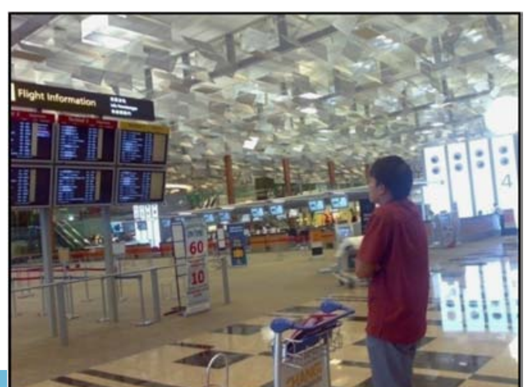


Plate 3.
Flight information display system in Terminal 3

There is also sharing of check-in counters by airlines under the same alliance umbrella. In this instance, the passengers checking into Singapore Airlines flights may also use other allied airline counters. In addition, in the check-in hall, lighting, air-conditioning outlets and baggage conveyor tracks are centralized and contained within the check-in islands. These are not scattered around. This one-location-based streamlining of services required a high level of strategizing at the design stage and appears to mirror the focussed factory technique.

Design for simplification and automation was also reflected in the check-in area. Simplification comes when there is more than one way to perform the check-ins. Passengers can choose between manual check-in, internet check-in, phone check-in and self-check-in. With advanced technology through the facilities installed, passengers can do their check-in over the telephone, short messaging service, facsimile check-in service and check-in via the internet (Changi Airport, 2006). The passengers can then just simply collect their boarding passes at the respective airline counters and at the time specified by the airlines. Procedural matters have now been simplified and left to automation to help the passengers complete the check-in procedures smoothly.

The JIT principle of quality control is also reflected in the check-in area. According to the IATA airport development reference manual, the operations in Terminal 3 strived to achieve a good level of service and comfort for the passengers by allocating a comfortable amount of space per passenger with first-rate service quality (IATA, 2004). For example, in meeting the requirements for a world-class passenger terminal like Terminal 3, the amount of space allocated to a standard passenger with a trolley cart should be in the range of between $1.3\,m^2$ and $1.8\,m^2$. There should also be space allocated for electronic self-check-in kiosks, including space for baggage acceptance. Apart from the sufficient space allocated for the passengers, there should also be large circulation areas and adequate seating to cater to the senders while waiting for the passengers near the check-in facilities. All these have been provided for in Terminal 3.

BHS

From the walk-through and interviews which formed part of the empirical portion of this study, it was noted that there are only two sections of BHS in Terminal 2, which are namely the weighing and tagging section and the induction section, respectively. Weighing the baggage will help check for the overweight and odd-sized baggage. Tagging the baggage means attaching the baggage with an identification label. The label allows airport employees to identify the baggage's origin of departure, destination and flight code that will be translated into a bar code for the BHS. This will facilitate the movement of baggage to the respective aircrafts and for identification purposes. The label is especially useful in locating lost baggage almost instantly. Induction means sending the baggage for security checks and sorting before transferring to the respective aircrafts eventually.

In Terminal 2, the processes of weighing and tagging are undertaken together in the same section. When there are numerous pieces of baggage to be weighed and tagged, the system cannot proceed on to the induction stage because only one baggage is allowed to be inducted at any one time. To counter this, the check-in desk employees have to move the baggage out of the section so as to allow one baggage to be inducted at any one time. This appears to result in inefficiency and interrupt with the baggage flow process.

Incorporating the practice of continuous improvement, the BHS in Terminal 3 is divided into three sections as illustrated in Figure 2. The first section is weighing, followed by tagging and lastly, induction. The first section of weighing is to determine if the checked-in baggage is of an acceptable weight and size. If so, the sensor by the side will "approve" the process and the baggage will then proceed to the second section for tagging. In this section, the baggage will be tagged by employees before proceeding on to the induction stage.

For passengers who check-in several bags, the tagging section can hold several pieces of baggage at any one time and the next ready tagged baggage can continue to go onto the induction section to be inducted into the take-away belt. Airline employees now need not get up from their seats to move the baggage unlike in the previous practice. Hence, in this case, there is elimination of motion (effort) waste by the employees.

After clearing the three sections of weighing, tagging and induction, the baggage will go on to the take-away belt to pass through the screening process. Thereafter, the cleared baggage will then move into the tilt-tray system to be transferred to the aircrafts. It can be observed that with this improved system, the processes in the BHS can be carried out continuously and without disruption.

In the BHS, it is noteworthy that a section of the conveyor belt system is slanted at an angle (see Plate 4). This is to facilitate smooth baggage movement by allowing the baggage to fall flat onto the conveyor belt. This was observed in the BHS in Terminal 3.

In contrast, airport employees in Terminal 2 have to get up from their seats to lay the baggage flat on the conveyor belt because the baggage might still be "standing" up straight after the induction stage. This is another example that reflects the JIT principle of uninterrupted work process for the airport employees. The improvement means that the employees need not waste unnecessary effort and motion. The enhanced feature does not interrupt the work of the employees by requiring them to constantly shift the baggage to lay the luggage flat on its side.

Another application of the JIT principle of continuous improvement is reflected in the odd-sized belt. In Terminal 2, every four check-in counters have one odd-sized belt. The odd-sized belt refers to the belt that takes in the odd size baggage of an unusual shape, size or weight to the basement for sorting before being taken to the respective aircrafts for loading. However, in Terminal 3, every two counters now share the use of one odd-sized belt that helps to enhance the efficiency of baggage handling.

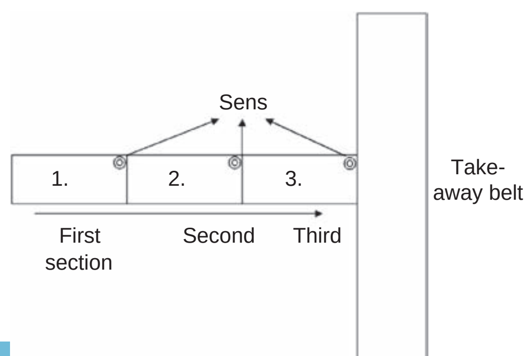


Figure 2.
Check-in Baggage Handling System in Terminal 3

Plate 4.
Conveyor belt system (three sections) in Terminal 3

Lastly, for passengers who wish to check-in their luggage early or have long connection times, an automated early baggage storage system is in place to store the luggage. Passengers are now able to check-in early, up to 48 hours beforehand. This reflects another example of the continuous improvement made.

Summary for check-in hall

The findings from the questionnaire survey, relating to the applicability of the JIT principles for the check-in hall is summarized in Table I. To reiterate, a five-point Likert scale was adopted in the survey questionnaire, with five representing "most applicable," one representing "least applicable" and three being neutral. Hence, if the average rating is far greater than three, then the said JIT principle in Table I is said to be highly applicable and vice versa.

Discussions

The features to be discussed in this section include the pinnacles, FIDS and conveyor belt system.

Pinnacles – signage with air-conditioning diffusers

The air-conditioning and mechanical ventilation system is one of the building elements in the departure hall and the transit mall that supply cold air at the occupancy level. This feature helps to save energy and is built into the interior architecture to save space. Nevertheless, after conducting the site walk-through and attendant measurements, it appears that there is a relatively stronger air draft in the landside such as the departure hall, the shops in level 3 and entrance to the passport control area.

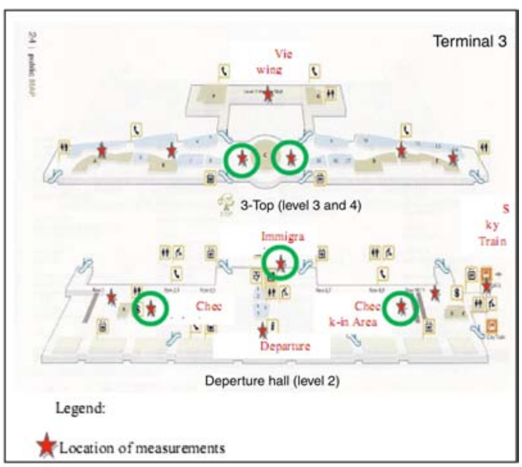
Table I.
Just-in-time (JIT) principles applied in the check-in hall

Airport features	Applicability of JIT principles	Applicability High	Neutral	Low
Pinnacles	Elimination of space and energy waste	✓		
Flight display information board (FIDS)	Uninterrupted work flow[a]	—	—	—
	Continuous improvement			✓
Check-in layout	Uninterrupted work flow – focused factory and design for simplification and automation	✓		
	Quality control	✓		
Conveyor belt system	Elimination of waste of motion		✓	
	Uninterrupted work flow[a]	—	—	—
	Continuous improvement	✓		

Note: [a]Excluded in the questionnaire as this seems to be an evident application of the principle

From the on-site measurements, the air velocity measured by the instrument, airflow anemometer, seems to be relatively higher in the areas circled in Figure 3. The departure hall area is specifically referred to in Plate 5, where the FIDS screens are located between two pinnacles. Strong cold air is felt when the passenger is checking for the information shown on the FIDS screens. This cold draft may cause some thermal discomfort. The same condition seems to be noted in the area in level 3 between the diffusers situated on top of the shops and the Chinese restaurant when one rides up from the escalator. The condition in this area may, however, appear to be acceptable because most people will not stay at the same spot for too long a time.

The last area is at the entrance of the departure passport control area (see Plates 6 and 7) where well wishers, in sending off their friends/relatives, tend to stay longer at



Source: Adapted from Changi Airport Group (2010)

Figure 3.
Measurement spots at levels 3 and 4 in Terminal 3 departure hall

the same spot. In this case, there are diffusers blowing directly at them from both the front and back directions. This spatial layout is only logical because many pe ople tend to gather at the area. However, the air may become too cold for some of them to feel comfortable.

Plate 5. Passenger may feel the cold draft when standing between two diffusers

Plate 6. Diffusers blowing directly at airport users from front direction

Plate 7. Diffusers blowing directly at airport users from back direction

FIDS

Some respondents do not appear to see this feature as an improvement because the FIDS in Terminal 2 have additional individual television clusters to supplement the consolidated ones seen in Terminal 3. However, this perception seems to be related more to the considerations of minimized congestion, smooth passenger route path and costs. If there are improvements to be made, functionality and the above-mentioned considerations need to be taken into account collectively to derive the best value for the FIDS.

Conveyor belt system

There appears to be scope for the conveyor belt system to be improved further. The angle of the conveyor belt system to receive the passenger luggage had been adjusted to better facilitate baggage movements. However, this does not seem to work that well in reality. There were instances where the baggage does not fall flat to be inducted into the take-away belt. In such instances, the airline employees will still need to get up from their seats to place the baggage flat on the conveyor belt. Elimination of motion (effort) waste is mirrored to a certain extent in such instances. The slope of the angle may perhaps need to be redefined for it to work well as intended. Alternatively, for example, an additional slope for the conveyor belt can be set up at the take-away belt. Enhancing this function can bring the conveyor belt system to deliver better effectiveness, thus reflecting the process of continuous improvement.

Conclusion

The lessons learned above are useful to support and conclude this study relating to the applications of the JIT concept for airport management, albeit in the context of the check-in hall in the first instance. Quite apart from its application in other areas of the built environment, the JIT concept was specifically examined in the context of the Changi International Airport through its planning processes and existing operations. This appears to be successful because the study was able to highlight the strengths as well as areas for potential improvements in the airport through the application of the seven JIT principles.

After reviewing the applicability of the JIT principles within the context of the airport features, it is noted that these principles were indeed relevant and useful for analyzing the various operational aspects found in the Changi International Airport. Hence, it is recommended that designers in the built environment consider the JIT principles consciously in their designs to deliver downstream spatial efficiency when the buildings are occupied and in use. Traditionally, designers work on the principle of "design follows functions." There is inherently nothing wrong with this working principle. However, if it is desirable for the JIT principles to surface in the building functions to further raise productivity, then designers should deliver on the basis of the more integrative "design follows JIT-driven functions" principle as illustrated in Figure 4. The concepts behind this integrative principle have been discussed by Low

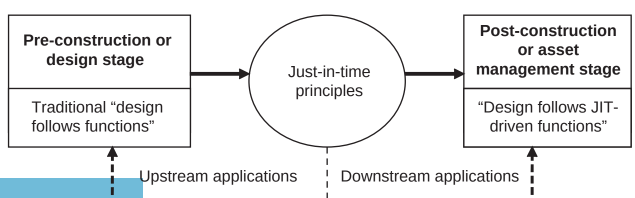


Figure 4.
The integrative "design follows just-in-time-driven functions" principle

and Show (2008) for which further reference is recommended for the working details. Before this revolution can take place, designers, project managers and asset managers must be educated on what the JIT concept and its supporting principles entail before integration can take place among them as stakeholders. Lastly, further studies are recommended on how the JIT principles can be applied in architectural, engineering and surveying consultancy firms to enhance their services delivery systems.

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Corresponding author
Low Sui Pheng can be contacted at: bdglowsp@nus.edu.sg