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Smart hospitality—Interconnectivity and interoperability towards an ecosystem

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ABSTRACT

The Internet and cloud computing changed the way business operate. Standardised web-based applications simplify data interchange which allow internal applications and business partners systems to become interconnected and interoperable. This study conceptualises the smart and agile hospitality enterprises of the future, and proposes a smart hospitality ecosystem that adds value to all stakeholders. Internal data from applications among all stakeholders, consolidated with external environment context form the hospitality big data on the cloud that enables members to use business intelligence analysis to generate scenarios that enhance revenue management performance. By connecting to smart tourism network, sensors and content extractors can assist to collect external information, and beacons to deliver context-based promotion messages and add value. The proposed model enables fully integrated applications, using big data to enhance hospitality decision making as well as strengthen competitiveness and improve strategies performance.

1. Introduction

The Internet brings boundary-less business environment and a strong competitive market. The oversupply of tourism suppliers, especially in the hotel industry, forces hoteliers to be innovative and creative and to find ways to differentiate and give prominence to their hotel among the large number of competitors. Smartness through interoperability and interconnectivity of all network partners increasingly enables hospitality organisations to develop their competitiveness through better understanding of customers and market conditions and develop their decision making processes. Smartness can effectively develop networks to create an ecosystem and dynamically interconnect all members. However, how to interlink the ecosystem is a challenging task as there is no standardisation among practitioners, and the stages of ICT development and implementation among members varies. Some hotels are on the technology frontier, as they adopt and upgrade to latest IT infrastructure and application systems, where some still use legacy technologies. More than one decade ago, Buhalis and O'Connor (2005) pointed out that technologies on ambiance and intelligence should be the focal point of technology developments in tourism. These included sensor technology, embedded systems, ubiquitous communications, media management and handling, natural interaction, contextual awareness and emotional computing. Advance technologies bring-in innovative and intelligence ways to control and monitor business. The Internet of things (IoT) and the Internet of everything revolutionize and reengineer business process as effectively disrupting the tourism and hospitality industries (Porter and Heppelmann, 2014).

Data is one of the most valuable assets in the hospitality industry. Contemporary hospitality management requires tremendous amount of data, including internal big data (such as hotel reservation history, cost analysis, guest history, revenue statistics and marketing statistics), and external context information collected from the external macro-environment such as economic, political and environmental data as well as nearby event profiles to conduct comprehensive business analysis. Big data collected from both internal and external services enable hospitality practitioners to make use of historical databases to forecast and predict business trends such as occupancy, rates and yield, labour costs and investment decisions (Zhang et al., 2015). However, current big data is still spread around the Internet without a standardized format. Therefore, users have difficulties to retrieve and consolidate them in a meaningful manner. Hospitality industry consists of countless direct and indirect business partners and collaborators. Every member of the network has comprehensive and detailed data to enrich their business analysis. However, no value can be created without these data is accessible, analysed and support decision making. The main objective of this study is to explore smart hospitality and propose a comprehensive ecosystem that takes advantage of interconnectivity and interoperability. With the support of big data, cloud service, sensors and

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ambient ecosystems can collect data dynamically, and decision support systems to support business functions in order to maximise the value for all stakeholders and intelligence. This will enable all actors to develop the collective competitiveness of the entire hospitality ecosystem and cocreate value for all stakeholders. The paper demonstrates how agile management using technology can be used, to support hospitality, as a highly-interconnected and networked industry.

This conceptual study extracted an extensive body of research from two disciplines. Research related to hospitality technology development and adoption was assessed and analysed to form the preliminary smart hospitality foundation. The foundation explored the developments of information technology in the hospitality industry and the implementation of technology in operations, management and customer interaction. This study adopted desk research as the method of data collection. Due to the recency of the topic, Internet reports were used for the developments in hospitality information systems, future trends, and challenges of smart hospitality. Resources searched included journal articles, conference papers, statistics and reports. In searching for resources, the following search words were used with a range of combinations of "ICT in hospitality", "ICT adoption", "innovation", "hospitality operation with ICT", "impact of ICT" "hotel ecosystem", "interconnect and interoperate", "barrier and challenge", "external macro-environment affect hotel management decisions", "Internet of things", "intelligent system", "smart hospitality system", "cloud and big data", and "data exchange". To ensure that the latest technologies and methodologies were extracted; only papers published after 2010 were included. Content analysis illustrated several key themes that drive smartness in hospitality and several themes were classified to explore development and critical success factors.

2. Hospitality ecosystem and smartness

Hospitality business involve a large number of direct and indirect stakeholders. Direct stakeholders play the key role in the hospitality ecosystem. They have direct business relationships with the hotel. Indirect stakeholders are those who are working closely with the stakeholders but do not have direct contact with the hotel. Direct and indirect stakeholders form an ecosystem that serves customers and creates value for all stakeholders. Fig. 1 illustrates the key members in the hospitality ecosystem and some of their sub-systems.

Hotel guests increasing real time service cocreation and unpredicted level of interactivity and engagement. Technology provide a range of tools to enhance, personalize and co-create their stay experience (Buhalis and Foerste, 2015; Neuhofer et al., 2015). Guests expect hotels to provide effective ICT applications for daily itinerary planning, information search, and for locating nearby activities. Communicating access voice, data and face-to-face hotel guest expect instant gratification as well as understanding of their personal desire and circumstances against the range of contextual factors, towards maximising value. Furthermore, business travellers require ICT to maintain effective and efficient business activities such as communications, remote office, document preparations etc. (Šerić and Gil-Saura, 2012). Free access and flow of data can access and allow key players in the ecosystem to enhance tourists' experience and empower the co-creation process. Operating and interacting with recent technologies such as augmented reality, virtual human, robots, and virtual reality can enrich their stay experience (Buhalis and Law, 2008; Insights, 2016).

The impact of ICTs in hotel management is mainly reflected in four major areas: strategic planning and revenue management; operations; marketing distribution and communication; and customer service and relationship management (DiPietro and Wang, 2010). Global competition among hotels is vigorous. Hotel managers and salespersons are required to implement competitive marketing and pricing strategies in order to maintain a reasonable profit level that satisfy the owner and investors requirements. Yield management relies on historical and contextual data to predict the future incoming business trends and recommend rate strategies (Smith et al., 1992). Contextual information macro environment changes and upcoming events are critical in this process (Buhalis and Foerste, 2015). Under globalisation, anything that happens around the world may affect the business environment directly or indirectly. Proactive and reactive strategies improve decision making and value cocreation and therefore influence the competitiveness and profitability of organisations.

Business partnerships also change due to the interconnectivity and interoperability capabilities of systems. Distribution as an element of marketing is the most influenced function that smartness revolutionised. Hotels need multiple distribution channels to expand their market share and to address different markets by using a comprehensive distribution mix. Major hotel business partners include airlines, travel agencies and tour operators, event organizers, and wedding planners conference organisers etc. Not only they bring customers to hotels, but also utilize hotel venues to carry their business activities and organise functions. In order to provide comprehensive service to hotel guests, each one of them work with a range of hotels independently. They also are involved with a large number of contractors according to the event activity nature and requirements. Hotels need to work closely

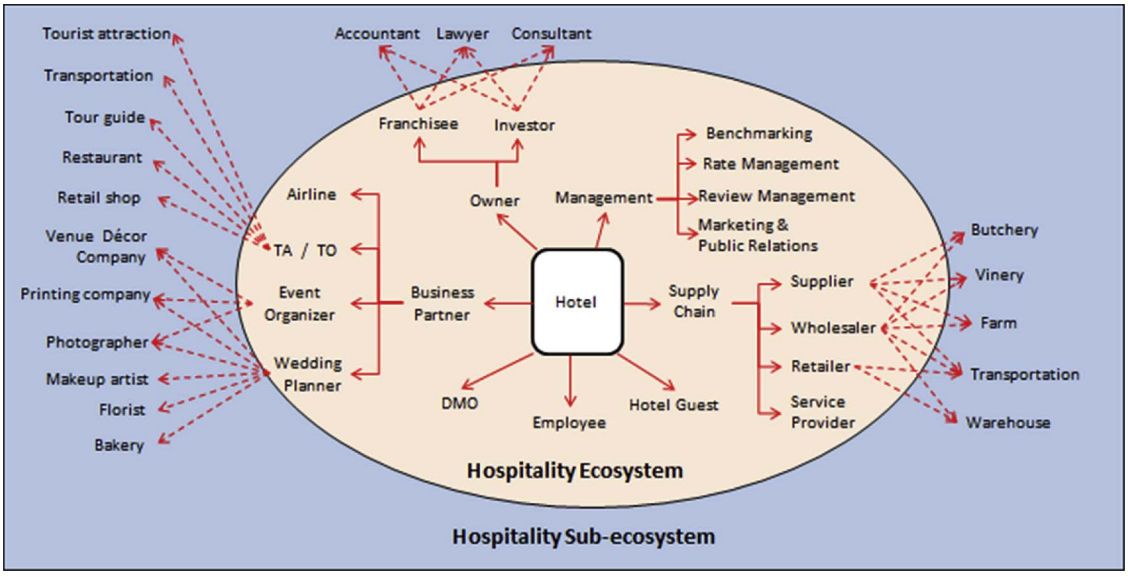

Fig. 1. Key Members in Hospitality Ecosystem and Sub-system.

with all cocreators of value to ensure services meet client needs. Coordinating these vast range of providers for cocreating customer experience can facilitated through interoperable "plug and play" systems. Any contractor can operate as a node to the network and use the ecosystem to build the range of services required. For example, as all information is easily accessed, and services are bookable on the ecosystem, a photographer who is commissioned for a wedding can be the first node of the ecosystem, and recommend the hotel, wedding car, hair and make-up artist based on established links and interoperability of system. These sub-ecosystems require coordinated customer information and external information to offer personalising services.

Marketing and distribution has been totally revolutionised as a result of smartness. To support distribution, travel agencies (TAs) and tour operators (TOs) established frequent communication and develop packages as well as maintain availability and rate update (Law et al., 2015). TAs & TOs work closely with large groups of travel entities such as attractions, transportations, tour guides etc. They constantly seek access to negotiated rates and current availability data, across different room types. They compare different hotel proposals to maximise their profit margins. Hotels equally seek to extend the range of distributors to can maximise their yield by increasing demand, occupancy and rates. They implement revenue management systems that take internal and external situations into consideration so their rate strategy changes dynamically for-profit maximisation. As travel intermediaries, TAs & TOs not only depend on online channels to distribute hotel rooms across the globe, but also need online platforms to allow customers to customize their products (Dev and O'Connor, 2015). Their relationship forms a sub-ecosystem that is attached to the hotel ecosystem. The members inside the sub-ecosystem work independently from the hotel, but also have other connections with plethora of hotels around the globe to ensure that they have choice of partners, facilities and rates. Thus, smartness supports the distribution functions and determines competitiveness.

Hospitality supply chains are also revolutionised through smartness. No hotel can operate without materials and supplies. Hotels have a large number of members in their supply chain, including but not limited to, food and beverage suppliers, guest room suppliers, HVAC (heating, ventilating/ventilation, and air conditioning) vendors, technology suppliers, maintenance and service providers, etc. These supply chain members also have groups of sub-contractors like butchers, farms, vineries, transportation companies, maintenance services, and warehouse etc. that form further sub-ecosystems (Zhang et al., 2009). Although these sub-ecosystems do not have direct contact with the hotel guests and only provide service among supply chain members. They are critical for the cocreations of hospitality experiences. Technology supports dynamic supply chains and manages the efficiency of these systems by enabling hotels to collaborate with partners who can provide suitable supplies within time and price constraints. Being smart and interoperable means that hotels have access to many sub-ecosystems and they can access information easily and efficiently to source the best solution for their needs. Interconnectivity means that the barriers to collaborate are minimized, effectively assisting hotels to constantly evaluate which subsystem is serving their needs and strategies better.

Human resources management and employees in hotel is also revolutionised through smartness, as hotels have access to a dynamic, global work force with a range of skills and abilities. They are also able to manage resources better by managing dynamically human resources according to fluctuations due to seasonality of demand but also special events and festivals using systems they may access rare employee specialisations. Automated hospitality operations can also reduce employee workloads from manual tasks and reduce human errors, increasing efficiency and effectiveness. The network can provide rich external contexts that hotel employees can use to obtain relevant information upon hotel guest inquiries. However, hotel management needs to balance job security of employees as they may worry that robots and system automation would replace them (Autor, 2015). As a result, they may be reluctant on ICT implementation.

3. Define smart hospitality

The concept of "smartness" refers to the integration of network of organisations and smart features that engage in interoperable and interconnect systems to simplify and automate daily activities and do add value throughout the ecosystem for all stakeholders (Buhalis and Amaranggana, 2015; Leonidis et al., 2013). Open online platforms enable private and public hospitality stakeholders to manage and orchestrate interactions in order to develop their business functions and access network resources. Interoperability is the key requirement in smart hospitality, as disparate systems can interconnect and exchange information, among public and private organisations. Business organisations attempt to develop enterprise solutions to automate system-to-system collaborations between trusted organisations for increasing productivity and reducing operation costs (Hopkins, 2000; Leung and Law, 2013). Hitherto these systems were often closed systems (propriety technology), with custom-made communication protocols which led to inflexible implementation of interconnection and interoperation. Hence most of organisations run propriety systems and used manual and analogue method to exchange data. Enhancing smart hospitality requires either standardisation of data communication or comprehensive interoperable infrastructures that enable automatic data interchange among systems.

Interoperability refers to the ability of disparate systems and business processes collaborate, support to data exchange and enable the sharing of information and knowledge (Maheshwari and Janssen, 2014). Rezaei et al. (2014) proposed four levels of interoperability. First level consists of interoperability of data, process, rules, objects, software systems and cultures. Second level focuses on knowledge, services, electronic identify interoperability and social network. Third level is cloud interoperability, which allows data stored on the cloud for boundaryless data access. Cloud computing supports an integrated "architecture of networks, software, sensors, human interfaces, and data analytics essential for value creation" (Harmon et al., p. 485). This enables comprehensive data storage and sharing as well as analysis capabilities for business entities. It acts as the core technology in the IoT that supports virtualisation, network service and intelligent technology. The last and highest level is interconnectivity and interoperability within the ecosystem. This enable all technologies and application able to communicate seamlessly.

To bring in smartness to the hospitality ecosystem, a common platform on the cloud must be setup to enable data communication among applications. Dynamic data can be interchangeable and all stakeholders should be able to obtain the required data for business forecasting and strategic planning. Handling big data warehouses requires a business intelligent systems which able to extract, transform and analysis blended data from internal and external sources (Ramos et al., 2015). A good example in hospitality is *STR* which collect data from independent hotels, aggregates data and enable subscribers to undertake strategic destination analysis and benchmarking against their anonymous competitors. In addition, contextual information such as weather forecast, events information annual celebration can assist hotelier in their decision making. There are countless external variables that can affect the demand and supply of tourists. The dynamic changes of the external environment have made all decision making and particularly revenue management strategies more complex and demanding. Smartness in hospitality supports the internal integration of operational data as well as the interoperability and interconnectivity with other shareholders in the ecosystem. It enables hotels to constantly exchange information throughout their value system and adapts their operation and strategies accordingly. Guests are in the centre of the process as dynamic interaction support personalisation and contextualisation of service and co-creation of experiences. More importantly, increasingly smartness bring disruption in the market place as new players change

the competitiveness forces.

3.1. Operationalising smart hospitality

Technology in hospitality not only acts as a tools to improve operation efficiency and effectiveness (Yu and Lee, 2009) but also co-create customer experiences (Neuhofer et al., 2015), improve organisational performance (Melián-González and Bulchand-Gidumal, 2016), and disseminate marketing information (Okumus, 2013). Electronic marketing campaigns now shift its focus to cocreate through social media. Customers' pre-purchase and on-site behaviour are influenced by the context posted on online platforms (Buhalis and Foerste, 2015). Social media provides a real-time interactive platform to communicate with existing and future customers before during and after their visit. Hotel and restaurant managers can effectively establish relationships with customers and increase customer loyalty. Any negative comments posted on these platforms can directly affect the company image and decrease customer visit and booking intention. Hospitality organisations such as *Marriott* develop control centres (MLive) that geofence and follow all relevant activity in real time to cocreate value with consumers dynamically. Applications such as *ReviewPro* that monitor the hotel online reputations, especially negative ones, from travel review websites enable hotel managers to keep tracked social medial reviews, analyse the context, and provide immediate responds.

In marketing and distribution statistics have shown that 59% of the travel reservation are made online (EuroStat, 2015). This indicates strong customer desire for online platform reservations. Customers use online travel agency (OTAs) websites as the key information and booking source for hotel reservations (Yacouel and Fleischer, 2012). Distribution management becomes crucial, as revenue managers and sales directors closely control and monitor their online room allotments and adjust room rates to maximise profit. As major OTAs are interconnected with Global Distribution Systems (GDS), international chained hotels have modified their applications to enable direct inventory control from the property management system (PMS) to online channels through channel management software (Leung and Law, 2013). However, there is little standardisation of data format among different OTAs websites, many independent hotel revenue managers have to update individual website manually, which might lead to oversell or fail to maximizing last-minute promotions. As custom-made interface software required additional cost, third-party online channel management systems arise to assist small and medium size hotel managers to monitor competitor's prices and manage their online room allotment and rate strategies (Fernandez et al., 2015).

Pricing is a key strategic function utilized by hotels to manage revenue (Kimes and Chase, 1998). Countless yield models have been introduced to assist revenue managers to maximise hotel room rate and occupancy, including revenue-maximizing prices for available room over time (Bitran and Caldentey, 2003); customer perception and loyalty (Lin and Huang, 2015; Noone and Mattila, 2009); distribution channel management (Toh et al., 2011), demand forecasting (Padhi and Aggarwal, 2011); setting booking control (Noone and Lee, 2011) etc. However, most of these models are mainly based on historical data to predict and forecast business trends whilst the external business environment is often overlooked as data is unavailable. Any recent changes in political and economic environment such as terrorist attacks and political instability that directly affect tourism demand and supply are not considered in the existing yield management systems. Organisations such as *Duetto* emerged to inform revenue management of how the external context and forecasted events can influence revenue management and different rates. In the future, strategic management shift from rely on historical and predicted demand analysis to dynamic, context and forecast based yield management offered by big data (Wang et al., 2015). Accurate forecasting can support the management of rates and increase profit. Instant rate strategies can be implemented immediately through channel management systems in order to reflect the recent tourism demand fluctuation and future forecasts.

Recently, some vendors make use of sensor networks (hereafter sensors) to collect data, and beacons to enhance communication with customers. Leonidis et al. (2013) proposed an intelligent hotel room platform for improving the ambient environment during the guest stay and provide required travel information. *Marriott International* introduced the IoT guestroom which allow hotel guest to interact in-room facilities via beacons and sensors. These systems can process internal data via sensors, such as guest location inside the room and then adjust the room environmental aspects such as temperature and luminance to improve stay comfortableness. Increasingly, interaction with external information such as weather at the hotel location and road traffic situation can improve even more the value cocreated.

Automated hotel operations with collaborative international and external marketing strategy can co-create a holistic and coherent experience to hotel guest. *Hotel Jen* of Shangri-la group start using autonomous relay robot to delivery items to guest room. *Henn-na Hotel* in Japan introduced the first robotic hotel with fully automated customer services. In-room robots allow a series of sensors inside the property that help the hotel to save energy and reduce waste. Robot concierge at the Hilton hotel connected to a cognitive system with machine learning abilities that can on one hand provide hotel and travel related recommendations to hotel guests, and on the other hand learn and improve its database via interaction with guests. Robots for cleaning and room service are currently on trial in using around the world. However, the current interactive robots are still based on existing static knowledge databases and were not so far able to integrate real-time external information and stakeholders; to the degree that will develop. Interoperability will be facilitated through 5G networks, were dynamic and up-to-date service will be affected. Increasingly, hotel internal application systems are becoming interconnected and interoperable with the wider ecosystem. However, due to the high development cost on non-standardized communication protocols and interfaces, many hotels only partially integrate their application system and fail to take advantage of the interconnectivity.

4. Towards a smart hospitality framework

An interconnectivity and interoperability framework is being spread throughout hospitality as an intelligence system that will revolutionise the hospitality industry. A fully integrated smart network should be able to sense, store, analyse and interpret data dynamically. From the capability of IoT and sensors, data from external environment can be monitored and extracted. Connecting smart IoT networks consist of three domain including network-centric, cloud-centric and data-centric (Jin et al., 2014). The business intelligence system required by hospitality must be well-defined with integrated analytical tools applied to historical data (Martins et al., 2015). Based on the related literature on smart network and application interoperability and interconnectivity, this study proposes an integrated smart hospitality network which includes sensors (for collecting external data), cloud computing (big data storage and processing), and intelligence applications that enables automated operations to support intelligent business decisions with minimum customization of communication protocols.

The growth of e-business transactions and the strong desire of data interchange automation, drive application systems toward interoperability (Berre et al., 2007). Interconnectivity and interoperability of applications empower ICT systems on data exchange in business processes, information sharing and knowledge management. Existing web applications adopt XML, WSDL and SOAP for information exchange. Opara and Gupta (2015) suggest to migrate the proprietary systems into web service platform to employ the standardized data interchange across platforms. According to Rezaei et al. (2014), industry is heading to four levels of interoperability: technical, (hardware/software, system and platforms that enable machine-to-machine communication), syntactic (well-defined coding of communication), semantic (clear

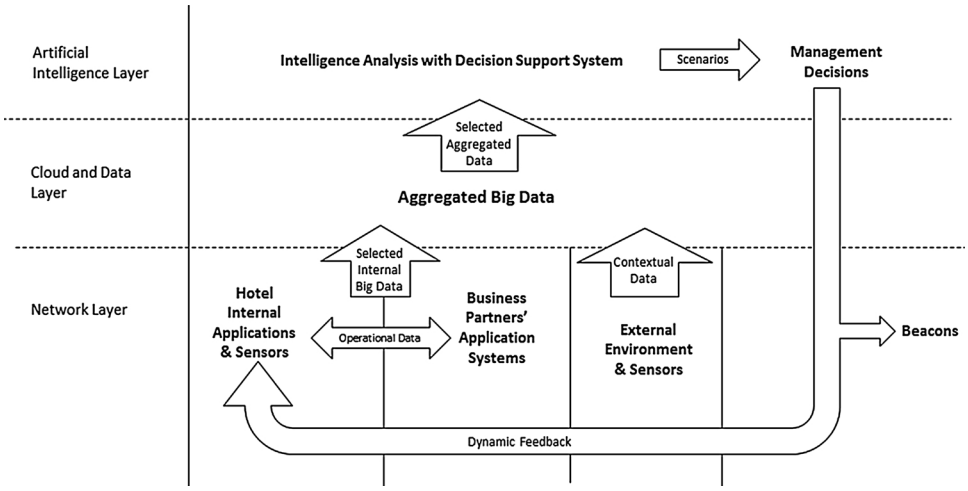

Fig. 2. Architecture of Smart Hospitality System.

definition of content and deals with human rather than machine), and organisational (organisations communicate effectively and transform meaningful data/information despite the use of different type of ICT system and infrastructure).

Fig. 2 illustrates the architecture of the proposed smart network which consists of three layers including: network layer, cloud data layer and artificial intelligence layer. The network layer interconnects different application systems and sensors among the ecosystem. Operational data are inter-exchangeable between hotel and business partners' application systems to reduce human error and increase operation efficiency. Cloud and data layer handle data aggregation and storage. External contextual data and selected internal data can be blended here to form the hospitality big data for sharing among the ecosystem. The last layer in this network is the artificial intelligence layer. Hotel can select desired data from the big data on the cloud for intelligence analysis and decision support. Various scenarios can be generated by the DSS to be available for hotel management. Appropriate scenarios selected can support optimisation hotel internal application systems and business propositions can be broadcasted by beacons. Hotel application system can be adjusted according the management decisions. Beacons can push context and location based messages to relevant actors and customers according to management marketing decisions.

4.1. Intelligence and network of sensors through the internet of things

The smart system can monitor the environment via sensors and IoT objects and carry out automatic activities. IoT functions into three different layers including smart systems (data acquisition); connectivity (data transmission); and analytics (actuate other IoT objects) (Chuah, 2014). An intelligent hotel building should be able to promote ecological, economic and social-cultural sustainable practices and generate value for all stakeholders (Kua and Lee, 2002). It should be environmentally friendly, flexible in space utilisation; effective and efficient on daily operations; use natural energy, measure dynamically the safety and security issues such as fire, earthquake etc. and meet stakeholders' expectations and flexible enough to adopt rapid changes in new technology (Ghaffarianhoseini et al., 2015). Smart hotels should use historical data from hotel systems to adjust the ambient environment (for example using smell/perfume systems to enhance particular moods) and atmospheres and achieve green management practices, including energy saving, indoor air quality management and eco-purchasing via effective waste management (reuse and recycle) (Jackson, 2013).

The proposed smart system should also be part of the smart tourism network. The whole smart system should monitor the environment via IoT objects and carry out tasks automatically. Sensors assist hotel applications to monitor the activities on going inside and outside the hotel (Yick et al., 2008). With the help of sensors, the information flow within the network is closely monitored and adopted by applications to work seamlessly. The IoT provides machine-to-machine interconnectivity of conventional physical objects via the Internet, and can intercommunicate and interoperate through remote controls by users (Hersent et al., 2011; Holler et al., 2014). Massive sensory information storage, computing and processing is the core of the IoT. Data from individual objects can be collected from internal and external environments and analysed by the smart system. As each physical objects around communicates with one another, the human intervention is minimal (Alsaadi and Tubaishat, 2015).

4.2. Big data supported a range of decisions making process

Big data is becoming critical in supporting decision making and engaging in different scenarios towards the optimisation of operations, revenue, cost and competitiveness. For example, forecasting models help to calculate business opportunities and income (Yu and Schwartz, 2006), and effectively handle the complexities of yield management (Donaghy et al., 1995). Traditional revenue management systems usually review five years of historical data (internal big data) to provide forecasting recommendations on pricing, rate rules, distribution channel management, and inventory optimisation (Denizci Guillet and Mohammed, 2015). Increasingly, revenue management makes use of artificial neural network, analytic network processes and fuzzy goal programmes to extract a better yield from multi-attribute decision making models from past profit, and long and short term goals (Padhi and Aggarwal, 2011). Contextual information analyses the condition of demand and supply and engage with all stakeholders dynamically to identify optimal pricing levels to maximise long term profit. Instant revenue-focused feedback can maximize revenue performance (Bendoly, 2013). Therefore, hotels are recommended to combine internal big data and contextual information from their external environment to carryout effective revenue management.

Artificial Intelligence (AI) not only facilitates human-to-machine interaction but escalates to machine-to-machine interoperation. It automates the aggregation and consolidation of data from multiple sources. For example, the systems can cross tabulate not only room revenue but also revenues from other departments such as casino, food and beverage outlets, spa and wellness that enable RevPAR (Revenue per Available Room) maximisation and optimising performance. Hitherto, AI has been involved in customer services, strategic planning and forecasting. External data and parameters will facilitate and much more comprehensive approach to decision making to maximise the engagement with resources towards enhancing competence. More

applications and usages are emerging to add value to all processes such as voice recognition enables hotel guest to interact with robot concierge and obtain required travel information at their own language and pace. AI technology incorporated with forecasting models increase the accuracy and bring hotel managers a better understanding on tourist demand and supply. This results to a better marketing strategy planning, financial management and manpower adjustments (Claveria et al., 2015; Huang, 2014). Other than data manipulation, AI can also help management to identify suspicious behaviour such as restaurant employees cash scams, which can reduce revenue lost (Collins, 2013), and deploy knowledge management for decision making (Stalidis et al., 2015). It can also support the management of the facility and the identification of period for maintenance or expansion.

5. Catalyst propelling smartness in hospitality

Business data volumes increase dramatically and enterprises demand to keep information for future management decision and planning. Hotel application systems and PMS have been implemented for decades to collect large amount of customer and business data (Leung and Law, 2013). Interconnectivity and interoperability of hospitality internal applications consolidate all data that generated from different application systems and form the internal big data. This can support benchmark business performance for arrival forecast, management decision making and strategic planning (Gupta and George, 2016) that generate an overview of the hotel historical business.

New e-business models change dramatically the operation workflow of hotel, especially on hotel booking and procurement process. Interconnecting hotel application systems with business partners' not only reduce human errors, increase the processing efficiency but also enable last minute promotions (Leung and Law, 2013). With the popularity of Internet and mobile applications, major hospitality software vendors increasingly launched their application on web/cloud service platforms. Web service platforms are accessible under open protocols which enables all kinds of web-based applications to interoperate and intercommunicate under a scalable operation platform. Nonetheless, when any business partner introduces new online trading environments, there is a potential of generating mismatched data within the supply chain. With the increasing number of web-enable applications, data interchange between applications introduced unprecedented convenience. Equally everything is easily replaceable. Fig. 3 illustrates the proposed smart hospitality network and the data flow within the ecosystem.

5.1. Internal data and smart hospitality support marketing, profitability competitiveness

Since these data are accumulated dynamically, hotel management decision makers can use them for forecasting and booking trends to achieve better yield performance (Ling et al., 2015). When application systems within the eco-system and sub-ecosystems are interconnected, dynamic data inter-change among applications can be done automatically with minimal human interaction required.

Hotels operate numerous application systems, such as PMS, POS, Sales and Marketing Systems (S&M) and energy and waste management systems etc. The transactional data generated should be centralized in a data warehouse for future reference. Sales and marketing managers can analyse historic reservation patterns and characteristics of hotel guests to forecast the upcoming business trends. Food and beverage managers can explore seasonal sales data and festive events to control food inventory and manpower. Back of the house departments such as housekeeping and engineering can schedule preventative maintenance according to the business forecast to avoid days with high occupancy.

Hospitality big data combines and consolidates data from both internal and external environments. Central databases accumulate internal big data that allows dynamic hotel and revenue management sharing. Some of these data are provided open on the cloud to enable the hospitality ecosystem to have access to a wider range of data. Hotels can utilize these consolidated data to increase competition power among rivals (Tsai and Yang, 2013), create personalized service to hotel guests, and analysed computationally to reveal patterns and trends (Buhalis and Amaranggana, 2015). Destination can also use open data to develop their collective competitiveness (Boes et al., 2016). The enriched database can enhance forecast accuracy for both the hotels and their business partners. These internal big data can help hospitality organisations to prepare comprehensive demand forecasting, website dynamic context, dynamic pricing, and improve their competitiveness (Vinod, 2013).

Marketing strategies and rate rules can be amended dynamically based on the historical customer travel pattern and events held. Internal big data not only assistant revenue managers to carry out more accurate rate and revenue forecast, but also assists hotel to save cost. By analysing travel patterns, hotel managers can forecast the upcoming arrival and arrange appropriate manpower effectively. They can also close wings/sections of the property during low occupancy periods.

From a procurement perspective, smart hospitality allows hotel to gain cost benefits from greater control on purchasing, procurement needs and improve decision making. With the interconnectivity of the hospitality ecosystem, additional suppliers can be easily identified, and the price of hotel supplies and amenities become transparent. However, even for international chain hotels, the usage of technology for data mining and analysing is still at an early stage and the application level of big data in the hospitality industry still low (Zhang et al., 2015).

5.2. External environment and internet of thing

With the globalisation of the business environment, anything happening on earth can directly affect travel motivation, hotel choice and stay experience. Hotel management should monitor the contextual situation proactively and reactively to constantly adjust strategies to these changes indicators (Buhalis and Foerste, 2015). Proactive responses include setup strategic plans, based on key performance indicators, that monitor global changes in the four major macro-environmental factors namely political, economic, social and technological. PEST factors can directly or indirectly impact hotel business and tourists' travel intention. Any political issues or implementation of new government policy can immediately affect the tourism business environment or tourists' travel intention. Tourist numbers may dramatically decrease or increase accordingly therefore hotel managers need to review and revise their marketing strategies dynamically upon different political conflicts (Alvarez and Campo, 2014; Cheng et al., 2016).

Economic-related issues such as currency exchange rate, tax rate, and bank interest rate etc. would also alter tourist's stay preference (Corgel et al., 2013). If the economic situation is not favourable, travellers may choose to stay in lower quality or cheaper accommodation, or vice versa. They would select high-end quality hotels or change destination all together (Tang et al., 2016).

Revenue managers can implement different pricing strategies to maintain the interconnected hotel competitiveness and maximize the profit according to the economic environment. Social factors such as life-styles and social trends (e.g. green hotel) can also alter tourists' hotel choice (Han et al., 2010). Technology can enhance and co-create hotel guest's stay experience (Neuhofer et al., 2015). Interconnecting the hospitality market ecosystem collect location-based information can enable better marketing promotion activities, such as packages, room allotment to travel agencies, rate war with new competitors etc. (Buhalis and Foerste, 2015; Ng, 2010). Hotel management should also react to all kinds of circumstances that occur at or around the hotel which can influence room demand. *MLive Labs* from Marriott do exactly as it has 5 centres that constantly engaging. Competition should also be monitor as new or refurbished accommodation provision or new

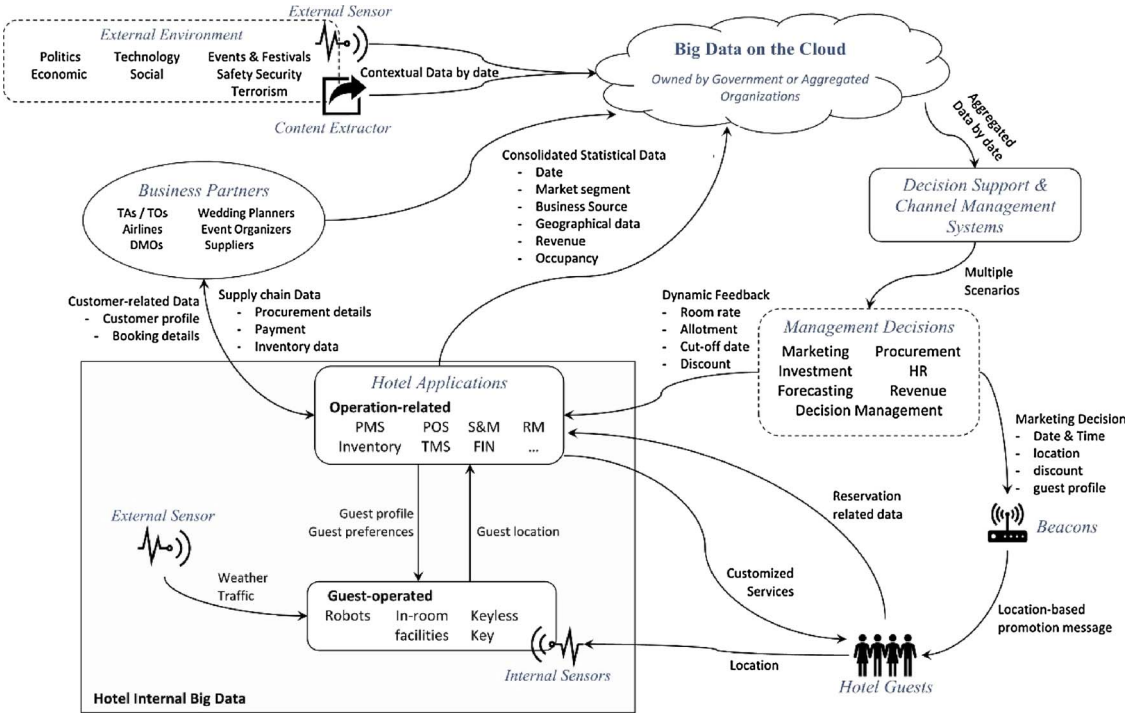

Fig. 3. Data Flow in Smart Hospitality Network.

services arrival may challenge a hotel and change the competition environment.

Social media play an important role in accommodation choice (Verma et al., 2012). Price is one of the factors that affect tourists' hotel choice but the content and creditability of user reviews also change tourist booking intention (Noone and McGuire, 2013). Management has to closely monitor and properly address negative comments to support how hotel image would be affected (O'Connor, 2010). Online reputation management is critical for any organisation in the future. As technology changes rapidly, flexible and scalable technology platforms should be able to adopt fast changes to fulfil hotel guest's needs. Monitoring can be automated via smart applications and alerts would be sent to the relevant manager for follow-up and feedback. Future smart application can extract customer's social profile and automatically retrieve their stay history from the internal big data for management to follow up.

Internet of Thing (IoT) and sensors installed inside the hotel and around the city collect substantial amounts of internal and external data such as hotel facilities availability, guest location, weather, road conditions and airport traffic situation etc. This information may not directly influence customers' stay experience but will affect the tourist overall impression and satisfaction of the trip (Jin et al., 2014). Hotel staff can immediately react to these situations by adjusting guest-related activities or recommending alternative activities when the weather conditions deteriorate. Hotels can install sensing devices to implement smart operations and management such as monitor hotel guest location, and deliver customized message via smart phone. Many hotels such as *Hotel Icon* in Hong Kong provide a smart phone "*Handy*" to guests to use during their stay offering value for guests. Hilton and Marriott hotel groups have start testing their smart guestroom which included personalized in-room ambience setting base on guest preference, and able to adjust using voice activated devices. Moreover, virtual assistance interacts with hotel guest for enhance their stay experience. Sensors installed inside kitchens can monitor the expiry date of food and beverage items and help chefs to plan the consumption sequence. Incorporated with artificial intelligence, sensors can also make use of the expiring food and beverage materials to design or recommend appropriate recipes. With the notification from RFID tags, par stock levels can also be setup and monitored so as to send out purchase order directly to suppliers to avoid out of stock, and reduce man power required on inventory take Fan et al. (2014). The proposed IoT location and its functions are illustrated in Table 1.

5.3. Smart hospitality based on big data on cloud

Smart hospitality cannot be deployed unless there is strong commitment on big data contribution from hospitality and tourism entities in the ecosystem. The big data contributed by each organisation is stored in a central database on the cloud. Hospitality big data on the cloud not only can collect statistics from hospitality and tourism entities, and context on related activities, but also allow timeless and boundaryless access. Handling hospitality big data on the cloud involves several key processes: transform hospitality and tourism organisations' processes and applications; sharing information; protect the data and ensure data compliance, consolidation; integrate and govern big data, build and manage the data view, and deliver the required data to individual organisation's data warehouse for business analysis (Ouf and Nasr, 2015).

With interconnected and interoperable systems, operational tasks can be carryout automatically. To maintain and create a comprehensive and real-time hospitality big data depository, practitioners in the ecosystem must be actively involved by sharing their business statistics on the cloud. Cloud storage can provide a global, secure, and standard platform for every member within the ecosystem to upload and share their data to the central database via different applications. The data warehouse can contain a completed historical picture of the industry to enable a comprehensive overview per destination, region and country. To protect the brand identity, internal big data from ecosystem members can be consolidated and processed to form different data cubes. Data cubes is a multidimensional matrix which contains series of data attributes, where each dimension represents some attribute in the database (Han et al., 2012). Each cell in the data cube represents the measure of interest. User can manipulate and process the cubes using analysis software, such as DSS because data has been processed and

Table 1
Recommended IoT Location.

IoT Location	Type of IoT/sensor	Function
Inside Hotel		
Guest Room	Movement sensor	Energy management system adjusted in-room environment and ambiance according to guest presence and their location inside guest room.
	Voice sensor	Voice activation controlling in-room devices such as curtain, lightings, room temperatures etc
	Temperature sensor	Measure room temperature ensure guest can stay with comfortable environment
	Door lock	Mobile app can act as keyless card for door lock system
	Wearable sensor	Monitor guest health situation during their workout and provide
Restaurant & Lobby	Location sensor Promotion beacon	Identify registered members presence and send push welcome message or events invitations
Hotel facilities	Availability beacon	Delivery availability notifications to hotel guest
Warehouse	Inventory tag	Detect item profile and location; Examine expiry date and par-stock level
Outside Hotel		
Building	Temperature sensor	Measure external temperature and make adjustment on energy management system
	Light sensor	Detect the sunlight and adjust the blinds and brightness of the lighting system
Roadside	Traffic sensor	Detect parking space and traffic situation
Social Network	Content sensor	Monitor social network and UGC sites content related to hotel and alert manager to feedback promptly; customer's stay history can be extracted from internal big data for management review.
PEST Data	Contextual data extractor	Extract PEST contextual data around the world and store in hospitality big data

consolidated and hotel's identity is hidden. The data dimension should include but not limited be to: hotel star rating; hotel type; hotel geographical location; seasons; customer nationality etc. Furthermore, sub-dimensions include 1) revenue generated from different revenue centre such as room rates and occupancy, food and beverage consumption, banquet and events, etc.; 2) cost incur such as food and beverage cost, room cost, energy cost, manpower cost etc. In fact, some organisations increasingly facilitate this process by offering sensors on and subscription bases. STR in particular collect data from across the industry and develops suitable information packs. External environment data can be extracted from the Internet via sensors or website spiders. Combining the PEST contextual data, such as policy changes, global economy, social media feedback, tourists' arrival, weather, upcoming event etc. the big data on the cloud can be enriched. Intelligence system analysis can categorize the collected data based on their characteristics and nature; form the "Hospitality Big Data" set and regular report that information that supports the industry. Every member of the hospitality ecosystem and sub-ecosystems can refer to this big data to prepare their own business strategic plans and dynamically manage their operations. Recently, *Duetto Research* accesses latest data on yield and revenue management among organizations and blends them with contextual information. *ReviewPro* also monitors reputation and allows organisations to access aggregated data. However, these data are only from hotel subscribers, and lack the wide range of data so the aggregated data cannot be generalized for the true hospitality situation.

5.4. Intelligent systems, management decision and dynamic feedback can support the strategic and operational decision making

Revenue forecast used to conduct based on historical data, however, with the massive data available online, revenue manager has more external factors to consider when undergoing the calculations. By combining data on demand, supply, customer perception, time window booking season, product description, price time window, heterogeneity of hotels and customers' preferences from big data on the cloud, DSS can generate various pricing scenarios for hotels that implement dynamic pricing strategies. Hotel managers can review the scenarios and select the most appropriate strategic plans that match the organisational KPIs (Kisilevich et al., 2013).

Hotel stakeholders can dynamically review scenarios generated from the DSS and enhance their strategic plans on various areas such as investment, HR plan, resource allocation, marketing strategies etc. For example, they can either increase their investment in hotel, increase or decrease capacity, decide on reservation or additions of outlets, decide the type of hotel to be open and the best location for building new hotel (Chou et al., 2008). These strategies can also arrange strategic alliance and expand business by collaborating with other members within the ecosystem. Hotel revenues can be maximized by implementing effective dynamic pricing strategies, according to the changes in macro-environment and customers' expectation (Noone and McGuire, 2013). Manpower can be adjusted according to the tourist arrival forecast. Personalized marketing promotion and services can be customized according to the customers' preference, location and recent external environment (Buhalis and Foerste, 2015). With the interconnected PMS, sales and marketing system, revenue management system, energy management system etc., system settings can be changed automatically per the DSS advice to the hotel management. Members of the hospitality ecosystem and sub-ecosystem can also make use of beacons to launch location-based marketing campaigns by actively pushing information to smart phone application to nearby customers rather than passively promote themselves via traditional mass media advertisement (Toedt, 2016). Energy conservation approach can also be examined by analysing various demand and supply scenario and DSS can come up with energy consumption alternatives for management consideration (Ayoub et al., 2014).

6. Conclusion: re-engineering the hospitality ecosystem through smartness

The proposed smart hospitality framework enables fully integrated internal and external applications and data exchange from the cloud, and obtains recent and historical data from big data. Standardisation of communication protocols and the development of a comprehensive ontology enable seamless communication among the ecosystem and sub-ecosystem partners and increases the effectiveness of interoperability among applications. Therefore hotel owners would have a seamless, transparent and flexible infrastructure with minimum the investment on customizing interfacing software. Managers can obtain comprehensive internal and external, empirical and contextual data and make use of DSS and yield management software for scenario testing to enhance their marketing and strategic planning (Pan et al., 2015). Although the smart hospitality network brings in advantages to the ecosystem, information inside the network become transparent and increases the competition within the ecosystem. The relationship and loyalty between ecosystem members and their sub-ecosystems is getting stronger as they can develop clusters of activity. Adding value to each stakeholder is of paramount importance. To encourage hotels to upload and share their business data to the big data on the cloud, they need to

maintain confidentiality, these data through aggregation and to ensure that clear value is provided through the process.

The proposed network enable all industry members to apply interconnected and interoperable systems. They support hotel companies to interlink their value systems, improve the collective efficiency and profitability of the ecosystem and strengthen their competitiveness. Hotel owners and investors are key stakeholders in the hospitality ecosystem long term. Profitability is the key principle in business and they expect reasonable return on investment. Technology changes rapidly and upgrades are required to catch up the changes and meet customers' need. One of the major investor concern's on implementation of smart hospitality platform is apparently the pay-off period, and to ensure that technology is current and state of the art (DiPietro and Wang, 2010). There is no direct correlation between advanced modern technology and profitability as it is the way hotels utilise technology that determine results. Hotelier also avoid being the first mover using innovative technology. Technology is consistently changing, and it is hard to identify the best timing to make purchase so that it is not outdated shortly after installation.

With the comprehensive and detail data generated, small and medium size hotels can also gain access to the big data and prepare strategic analysis. As a result, international hotel chain may no longer have advantage of having comprehensive world-wide data collected or bought from research organisations.

Pioneers who initiate and develop online platforms, invite key players to join this network and add value to their operations can be the leader in the smart hospitality industry. Successful organisations should have the ability to standardize communication protocols and data formats to establish reliable and secure cloud-base data warehouse. Gaining trust and credibility from key members to upload their business data on the cloud without hassle is critical to consolidate individual business statistics and context from the external environment, and conduct intelligent analysis on the data collected.

To develop the smart hospitality network, several challenges need to be addressed and overcome. First is the ownership and subscription fee of the data. Centralized data warehouses and data centres for big data have to be setup. However, the owner of platform (hardware and infrastructure) cannot claim to own the data as they are contributed by industry practitioners and public entities. If the ownership of the data cannot be elucidated, no hotel practitioners would agree to upload their business data to the big data. Moreover, accessibility of the data is also a concern. If a paid subscription is required, hoteliers would hesitate to enrol on this service unless clear value is identified. On one hand, they need to pay for the service; and on the other hand, they are required to upload their business data to the cloud. This would affect their decision to join the network. To overcome this barrier, this network can be setup by trusted industrial association to maintain a neutral position and provide to industry practitioner as a tool that is part of the value preposition.

However, information sharing across organisation always faced several barriers, including intra-organisation, inter-organisation, technical and political issues. Inter-organisation issues such as lack of trust to the new system, and exposure of business data to competitors can impede the implementation of hospitality big data for the industry. Any concern from ecosystem members can lower their participating intention on data contribution to the hospitality big data. To eliminate doubts and concerns from individual executives, public available data on the cloud should be consolidated, processed, and maintained anonymously so that no organisation identity or customers' details can be accessed or recognised by competitors. Nevertheless, the benefits of smartness remain the strategic and reengineer the industry.

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