Design of Business Intelligence System for Point-of-Sales Software in Full-service Restaurants

Miss Lalida Chunhasomboon

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Engineering in Engineering Management

(CU-Warwick)

Faculty of Engineering

Chulalongkorn University

Academic Year 2018

การออกแบบระบบวิเคราะห์ข้อมูลทางธุรกิจสำหรับโปรแกรมจัดการหน้าร้านในร้านอาหารประเภทบริการครบวงจร

น.ส.ลลิดา ชุณหสมบูรณ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2561

Thesis Title	Design of Business Intelligence System for Point-of-Sales Software in Full-service Restaurants
By	Miss Lalida Chunhasomboon
Field of Study	Engineering Management
Thesis Advisor	Assistant Professor NARAGAIN PHUMCHUSRI, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Engineering

..... Dean of the Faculty of Engineering
(Professor SUPOT TEACHAVORASINSKUN, D.Eng.)

THESIS COMMITTEE

..... Chairman
(Professor PARAMES CHUTIMA, Ph.D.)

..... Thesis Advisor
(Assistant Professor NARAGAIN PHUMCHUSRI, Ph.D.)

..... Examiner
(Assistant Professor PISIT JARUMANEEROJ, Ph.D.)

..... External Examiner
(Associate Professor Vanchai Rijiravanich, Ph.D.)

ลลิดา ชุณหสมบูรณ์ : การออกแบบระบบวิเคราะห์ข้อมูลทางธุรกิจสำหรับโปรแกรมจัดการหน้าร้านในร้านอาหารประเภทบริการครบวงจร. (Design of Business Intelligence System for Point-of-Sales Software in Full-service Restaurants) อ.ที่ปรึกษาหลัก : ผศ. ดร.นระเกณฑ์ พุ่มชูศรี

ร้านอาหารขนาดเล็กและขนาดกลางต้องเผชิญกับการแข่งขันที่เพิ่มขึ้นเนื่องจากการเข้าถึงที่ง่ายขึ้นและความต้องการของลูกค้าที่เพิ่มขึ้นจากการรีวิวร้านอาหารและแอพพลิเคชั่นสั่งอาหาร การที่ร้านอาหารจะแข่งขันในตลาดได้อย่างสูสี นอกจากการรู้รายได้แล้วเจ้าของร้านอาหารยังต้องการทราบถึงประสิทธิภาพในการจัดการร้านอาหารในด้านอื่นๆ เช่น การดำเนินงาน ระดับสินค้าคงคลัง และคุณภาพการบริการ อย่างไรก็ตามโปรแกรมจัดการหน้าร้าน (POS) ที่มีในปัจจุบันยังไม่มีการบอกถึงประสิทธิภาพในด้านอื่นๆ ทำให้เจ้าของร้านไม่สามารถที่จะรู้และปรับปรุงมิติอื่น ๆ ของการจัดการร้านอาหารได้ จึงเป็นผลให้บริษัทเล็งเห็นถึงช่องว่างของตลาดนี้ที่บริษัทสามารถตอบโจทย์ได้ รวมถึงโอกาสที่จะมอบคุณค่าใหม่ให้กับเจ้าของร้านอาหารเพื่อดึงดูดผู้ใช้ใหม่และรักษาผู้ใช้เดิม ระบบวิเคราะห์ข้อมูลทางธุรกิจ (BI) พร้อมหน้าจอแดชบอร์ดจึงเป็นสิ่งที่บริษัทต้องการจะพัฒนาเพื่อตอบสนองความต้องการของตลาด

การออกแบบระบบวิเคราะห์ข้อมูลทางธุรกิจสำหรับโปรแกรมจัดการหน้าร้านในร้านอาหารประเภทบริการครบวงจร ประกอบไปด้วย 3 ส่วน คือ ดัชนีชี้วัดผลงาน (KPI) การแสดงผลบนแดชบอร์ด และคลังข้อมูล ขั้นตอนแรกคือการค้นหาการวัดผลงานในด้านต่างๆของร้านอาหารจากวารสารวิชาการและผู้เชี่ยวชาญในอุตสาหกรรมร้านอาหาร ค่าชี้วัดหลายๆตัสนถูกนำมาผ่านกระบวนการคัดสรรจากกฎเกณฑ์ต่างๆและแบ่งประเภทตาม Balanced Scorecard เพื่อเป็น KPI ที่จะแสดงบนแดชบอร์ด หลังจากนั้นแต่ละ KPI จะได้รับการเพิ่มเติมบริบทและการเปรียบเทียบแล้วจึงเลือกการแสดงค่าที่เหมาะสมตามประเภทและความสัมพันธ์ของข้อมูล จากนั้น KPI เหล่านี้จะถูกจัดกลุ่มและจัดเรียงให้พอดีกับแดชบอร์ดขนาดหนึ่งหน้าแท็บเล็ต ส่วนประกอบสุดท้ายคือการออกแบบคลังข้อมูลเพื่อเป็นแหล่งข้อมูลใหม่ที่จัดเก็บข้อมูลในรูปแบบที่เหมาะสมกับการนำไปทำรายงานและการวิเคราะห์ข้อมูล ซึ่งสำหรับคลังข้อมูลนี้ Dimensional modelling จะถูกนำมาใช้เพื่อออกแบบโครงสร้างข้อมูลไปถึงระดับที่นักพัฒนาซอฟต์แวร์สามารถนำไปใช้เขียนระบบได้ในอนาคต

หน้าจอแดชบอร์ดแบบใหม่ถูกประเมินโดยผู้ใช้งานปัจจุบันของ POS ของบริษัทจำนวน 20 ราย โดยที่ผู้ประเมินแต่ละคนให้คะแนนความพึงพอใจของแดชบอร์ดปัจจุบันและแดชบอร์ดแบบใหม่จาก 1 ถึง 10 ซึ่งผลการให้คะแนนได้ผ่านการตรวจสอบเพิ่มเติมโดย Wilcoxon signed rank test เพื่อพิสูจน์ว่าผู้ใช้มีความพอใจในแดชบอร์ดใหม่มากกว่าอันปัจจุบันอย่างมีนัยสำคัญทางสถิติ โดยรวมแล้วผู้ใช้ให้ความเห็นว่าแดชบอร์ดแบบใหม่นั้นแสดงข้อมูลที่มีประโยชน์มากขึ้น นอกจากนั้นผู้ประเมินได้ทำการเรียงลำดับ 3 KPI มีประโยชน์มากที่สุด และ 3 KPI ที่มีประโยชน์น้อยที่สุด ประกอบกับความคิดเห็นอื่นๆ ผู้วิจัยได้นำมาปรับปรุงแดชบอร์ดอีกครั้งเพื่อออกเป็นแดชบอร์ดเวอร์ชั่นสุดท้ายที่แก้ไขแล้ว

โดยสรุปโครงการนี้เป็นงานวิจัยแรกที่ออกแบบระบบวิเคราะห์ข้อมูลทางธุรกิจโดยใช้ข้อมูลจากโปรแกรมจัดการหน้าร้านสำหรับร้านอาหารบริการเต็มรูปแบบ โดยที่ KPI จะเน้นให้มีประโยชน์และสามารถนำไปสร้างคุณค่าทางธุรกิจได้และการออกแบบแสดงผลที่ทำให้เข้าใจง่าย โดยรวมนั้น KPI และแดชบอร์ดได้รับผลตอบรับที่ดี มีประโยชน์ในการวัดประสิทธิภาพการทำงานซึ่งเจ้าของร้านสามารถนำไปพัฒนาการจัดการร้านอาหารได้ดีมากยิ่งขึ้นในลำดับต่อไป

สาขาวิชา	การจัดการทางวิศวกรรม	ลายมือชื่อนิสิต .....
ปีการศึกษา	2561	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

5971213221 : MAJOR ENGINEERING MANAGEMENT

KEYWORD: dashboard, key performance indicator, restaurant, business intelligence

Lalida Chunhasomboon : Design of Business Intelligence System for Point-of-Sales Software in Full-service Restaurants. Advisor: Asst. Prof. NARAGAIN PHUMCHUSRI, Ph.D.

Small and Medium-sized restaurants are faced with increasing competitions due to the rise of food reviews and food delivery mobile applications which increase accessibility and customer demands. In order to thrive in this competition, restaurant owners seek to know their performance beyond sales number as there are other aspects of restaurant management such as operations efficiency, inventory, and quality of service. However, the current offerings by various POS in the market do not provide such performance measures, making it impossible for owners to know and improve other dimensions of restaurant management. As a result, the case-study company identified the gap to fulfil this need and also an opportunity to provide a new value proposition to users, attracting new users and retaining existing ones. Thus, a business intelligence (BI) system with a dashboard was selected as the solution.

There are 3 components to build the BI system for full-service restaurants: Key Performance Indicators (KPIs), dashboard display, and data warehouse. For KPIs, a variety of performance measures of restaurants was researched from academic journals and industry experts. Critical ones were selected based on a set of criteria and grouped together according to Balanced Scorecard to form a set of Key Performance Indicators (KPIs). Next, each selected KPI was carefully enriched by context and comparison, then chosen an appropriate display medium based on data types and relationships. Then, these KPIs were grouped and arranged to fit a 1-page tablet-sized dashboard. The last component is the data warehouse which was necessary to provide a new data source that contains aggregate values and is structured appropriately for reporting and analysis on the BI system. Dimensional data model was used to design the physical data model for software developers to implement in the future.

The new design was then evaluated by 20 respondents who are the current users of the POS and current dashboard. They were asked to rate the current and the new design separately on the scale of 1 to 10. The rating results were further validated by Wilcoxon signed ranked test and it could be statistically shown that the new design is preferred by users to the current one. Users find the new dashboard more useful in providing them with relevant performance measures. Apart from the ratings, respondents also ranked their top 3 and bottom 3 KPIs and provided qualitative suggestion on the new design. Feedbacks were consolidated and the revised final version of the dashboard was created based on those feedbacks.

In summary, this research is the first to create a BI system based on POS software for full-service restaurants. The KPIs were selected to be useful and practical while the display was carefully designed based on the principle of visual perception and enriched by useful context to encourage critical analysis. The set of KPIs and the new design were well-received as they provide an effective way to equip restaurant owners and managers with valuable performance measures to help manage their restaurants better.

Field of Study:	Engineering Management	Student's Signature .....
Academic Year:	2018	Advisor's Signature .....

ACKNOWLEDGEMENTS

I would like to thank my thesis advisor, Assistant Professor Dr. Naragain Phumchusri, tremendously for her relentless support and guidance throughout this research, giving up several of her weekends and work hours to help me complete the thesis. I extremely appreciate her help and advice.

I also would like to thank my parents who pushed and supported me in every way they could throughout the journey. Moreover, I have to thank the product and sales teams who gave me valuable feedback to improve my ideas and solidify the requirements of this research. Thanks to my boss who allowed me to take time and resources of the team to research for this project.

And lastly, I thank myself for finally completing the Master degree.

Lalida Chunhasomboon

TABLE OF CONTENTS

Page

Proposed Chulalongkorn Thesis Declaration

in Compliance with

Chulalongkorn University Regulations on Education in Cross-Institution Programs 2017 and

Graduate School's Executive Committee Meeting No. 12/2560 Resolution

Dated 21 December 2017

Declaration

I hereby declare that this thesis has been composed by myself and that it has not been submitted, in whole or in part, in any previous application for a degree. Except where stated otherwise by reference or acknowledgment, the work presented is entirely my own.

The entirety of this work has been submitted for dual degree between the Master of Engineering in Engineering Management programme, Chulalongkorn University and the Master of Science in Engineering Business Management programme, University of Warwick.

List of Figures

List of Tables

Chapter 1 Introduction

1.1 Background of Case-Study Company

Thailand's restaurant industry has been growing year on year. In 2018, Thailand's restaurant business would have a total value of 411- 415 billion baht which is a 4-5 percent growth from 2017 (KResearch, 2018). Small and medium-sized restaurants account for 69% of the total market value (KResearch, 2017). In recent years, restaurant review websites such as Wongnai and social influencers have sparked a lot of customer interests in small and medium-sized restaurants. Restaurants gain more visibility in the online world, bringing more people to the physical stores. In addition, the rise of food delivery mobile applications such as GrabFood, Get, Foodpanda, and Line Man have increased accessibility to small and medium-sized restaurants and provided convenience for faraway customers to order. Thus, restaurants are no longer localised. This resulted in higher customer demand and thus increased competition among small and medium-sized restaurants.

While an increase in demand is good for increasing sales and customers for restaurants, it adds more complexities to restaurant operations and processes. Very few technologies have been introduced to help small and medium-sized restaurant cope with more demand and manage operations more efficiently to survive in the more competitive landscape. In Thailand, small and medium-sized restaurants are usually run by owners and a small set of staff. Orders are recorded by hand and give to chefs in the kitchen. Oftentimes, ordered are forgotten or lost on the way. Also, because orders are written, there is no proper recording for convenient accounting and reconciliation at the end of the day. Prices are sometimes calculated wrongly and frauds can easily happen. Some restaurants use an old version of Casio electronic cash register as shown in Figure 1 below. This hardware stores data offline in a limited quantity and there is no back up of in case of a breakdown. It also cannot produce reports or do analysis. The

interface requires memory work and thus is hard to teach new staff to use. Moreover, it does not accommodate integration with newer online technology.

Figure 1 Casio TK3200 Cash Register (POS Central, n.d.)

Large or chain restaurants have the fund and capability to invest in a Point-of-Sales (POS) system that has sophisticated functions to answer the need for complicated front-of-house operations, staff management, accounting, tax reporting, reservation, inventory and etc. On the other hand, small and medium-sized restaurants do not have enough resources to invest in such a system and also do not require such advanced functionalities. Hence, there is an unmatched need for a more lightweight and affordable POS to serve small and medium-sized restaurants. Thus, the case-study company saw an opportunity to disrupt the market by providing an affordable mobile POS application that has functionalities suitable for these sizes of restaurants. It is the vision of the case-

study company to become the number 1 provider of POS mobile application in Thailand.

The case-study company is a software developer and distributor. One of the main products is the POS software specifically for small and medium-sized restaurants. The features and functionalities are designed to suit operations of those sizes. The software is in the form of a mobile application intended to be used on tablets. It is compatible on both iOS and Android operating systems. Table 1 below summarises the major functions and their descriptions of the case-study company's POS. The functions are separated into three groups:

(1) Front-of-house operations refer to activities that occur in the areas of restaurant where customers are allowed. The operations involve direct interactions with customers such as order taking and payment. It is mostly used by restaurant staff.

(2) Backend management refers to behind-the-scene operations such as configuring menus, prices, inventory, and any other settings that rarely involve customers. This is mostly used by owners and managers.

(3) Dashboard and reports are summaries of sales and other information. Dashboard presents near real-time information while reports show historical details for deep-dives.

Function	Description
Front-of-House Operations	
Order and Bill Management	Open bills, edit, cancel bills Record orders into a table Send orders into kitchen printers
Payment	Summarise bills Apply promotion Calculate VATs, service charges Split payment Receive payments via cash, credit cards Refund Print receipts and open cash drawer
Backend Management	
Menu	Create and edit items (name, price, and image) Create and edit item modifiers Categorise items and arrange them into tabs
Table	Create tables (size, location, and shape) Arrange tables to reflect real setting Show status of table (free, occupied)
Inventory	Create and edit inventory levels Link menu items to ingredients and portion required Check real-time inventory level Send alerts when inventory level reaches threshold
Staff	Create and edit staff (account, mobile, role) Classify staff into roles Create shifts for staff
Membership	Create and edit member details Store members' transactions and points

Promotion	Create and edit promotions on food items Create and edit promotions for members
Dashboard & Reports	
Sales	Real-time, daily, weekly, monthly, customisable duration
Top selling	Items, modifiers, categories
Payment	Method, refund, cancelled

Table 1 Summary of Functions of Case-Study POS

In Thailand, there are 2 main competitors but there is no clear market leader. As mentioned above, because most small to medium sized restaurants still adopt the manual method, the market for POS is still a blue ocean where there is no clear winner and still plenty of customers. Nevertheless, the target market overlaps because the functions offered by the three POS are similar and catered to small and medium-sized restaurants. Table 2 below compares the functionalities of the case-study POS and those of the other two competitors.

Functions	Case-study Company	Company B	Company C
Front-end Operations			
Order and Bill Management	✓	✓	✓
Kitchen Order	✓	✓	✓
Payment	✓	✓	✓
Back-end Operation			
Menu Management	✓	✓	✓
Inventory Management	✓	✓	✓
Staff Management	✓	✓	✓
Table Layout Management	✓	✓	✓
Recipe Management	✓	✓	-
Discount & Promotion	✓	✓	✓
Membership	✓	✓	-
Tax and Service Charge	✓	✓	-
Others			
Offline mode	✓	✓	✓
Dashboard & Reports			
Online Sales Records	✓	✓	✓
Download data and reports from cloud	✓	✓	✓
Email reports	✓	✓	✓
Web portal for owners to manage shops	✓	✓	✓
Mobile app for owners to manage shops	✓	-	-
Simple Data Analysis (Graphs, Pie Charts)	✓	✓	✓

Table 2 Comparison of Functions between Top 3 POS Software in Thailand

As shown in Table 2 above, all the top 3 products in the market offer similar functionalities because they all try to match each other and have the same target customers. Some differences lie in user experience, flows, and some capabilities of some functions. The similarities in functions makes customers' bargaining power very high as they can easily switch to other applications. Thus, developing a new unique value proposition becomes one of the critical challenges that the case-study company would like to tackle in order to differentiate itself and stay ahead of competitors.

As a startup in growth stage, the goal of the company for this product is to acquire as many users as possible and make sure that they regularly use the POS on a daily basis. The growth framework used to evaluate performance is the Pirate metrics or the AARRR framework proposed by McClure who is a venture capitalist and the founder of a well-known 500 Startups (Balke, 2017). According to McClure, AAARR consists of

- **Acquisition** concerns how people discover our product and become our users. For the case-study company, customers mostly come from direct approach from sales team. We consider a successful acquisition when new users download the application and register by creating a new account. As a protocol, sales team would also provide on-the-spot training to teach owners, managers, and staff on how to operate the application.
- **Activation** concerns the first experience the customers have with the product after registration. They need to appreciate the real value of the product by using it themselves. For the case-study company, users are considered as activated if they start using the application by themselves within a week after the initial training.
- **Retention** looks at people who come back to use the product. In the case of POS, there should be activities almost every day since most restaurants open 6-7 days per week. After a month, the case-study company looks at how many

users are still using the application regularly. This group is a potential revenue generator and it is critical for the company to retain them.

- **Referral** is when customers love the product so much that they become our advocates and recommend others to use it.
- **Revenue** is when loyal customers subscribe to the POS service. This is when the company starts to make money.

This growth framework is a funnel as shown below in Figure 2. The company adds another stage at the beginning which is Approach to determine the number of restaurants approached by sales team. There are fewer users going down the funnel as users drop off. The company looks at the percentage drop-off of users between each stage. Figure 2 shows, on average, how the funnel performance looks like for the company. Number of users shows the number of users qualified to be in each stage.

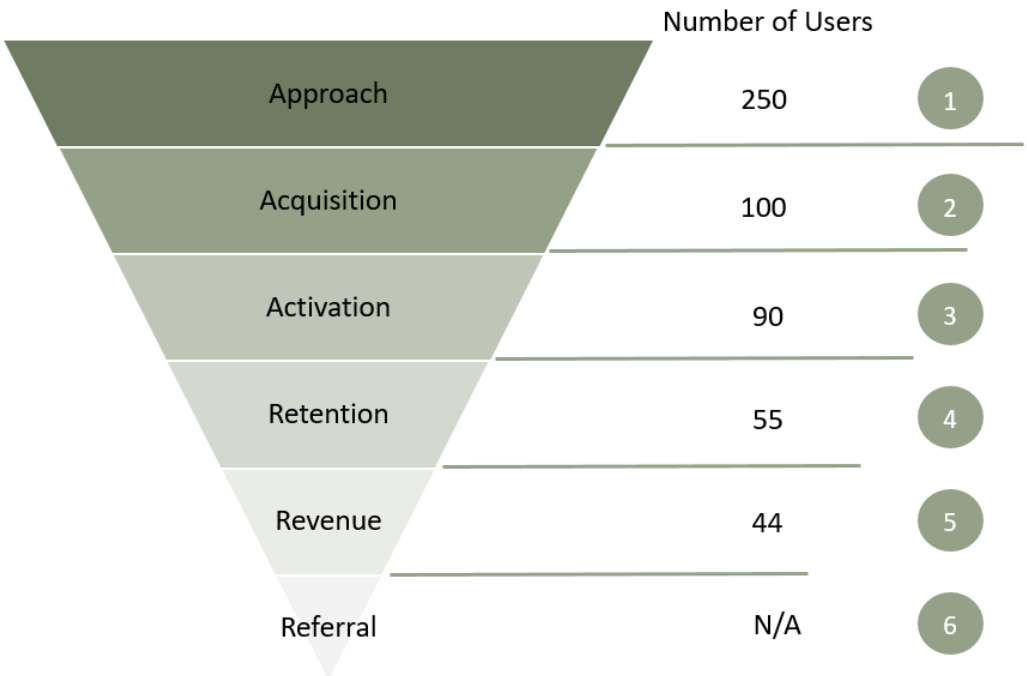


Figure 2 Performance of the Company's Pirate Metrics

Referring to Figure 2 above, the drop-off of users from category 1 to 2 (60% drop-off) and from category 3 to 4 (39% drop-off) are the largest. There could be many possible reasons for the drops. In order to get a deeper understand, the company conducts routine feedback collection through field visits and customer service to get opinions and suggestion on the product. The reasons for the drop-offs were gathered from sales team as follows:

Drop-off from Approach(1) to Acquisition(2):

- Some restaurants are already using other POS and are not willing to convert as they already invested a sunk cost in it or staff is already familiar with it, thus resisting to change.
- Some owners consider other brands at the same time. The functions or value proposition are not attractive enough to convince them to choose the company's POS over the others.
- Some do not find it a necessity to have because they are too small or traditionally run by family.

Drop-off from Activation(3) to Retention(4):

- They failed to incorporate the use of POS into their daily operations. Staff was not willing to use or owners did not diligently enforce.
- Once they do not use regularly, they would not reap the full benefits that POS can offer. Over time, they would not see the values and stop using.

These reasons shed some insights into why people did not adopt the POS but we also would like to know what other functions can be added or improved in order to achieve better acquisition and retention rate. From the feedback, users were satisfied with the overall functionalities and performance of the POS. It is clear that the POS helps improve operational efficiencies, reduce errors, and speed up accounting process. Further probe was done to find out what else they would like to have in order to improve the

product. Often, owners voice a common request on wanting to know the restaurant status and performance so that they can monitor and improve. This is especially so for owners who are physically away from their restaurant and would like to know performance beyond sales numbers.

Figure 3 below shows the current dashboard of the case-study POS, translated from Thai to English. As shown in Figure 3, the current dashboard only shows sales-related information including daily sales, current open bills, payment methods, and best-selling items.

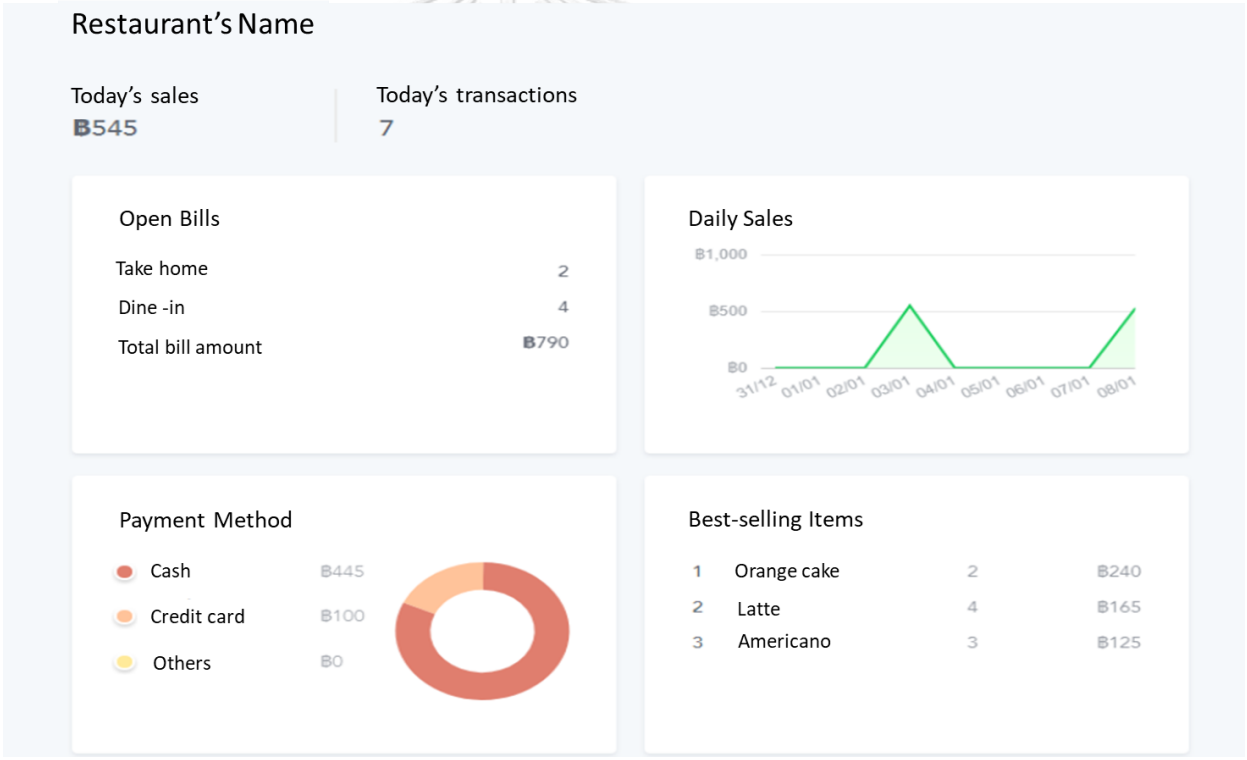


Figure 3 Case Study Current Dashboard

Figure 4 and Figure 5 below show a compilation of competitors and international POS dashboards.

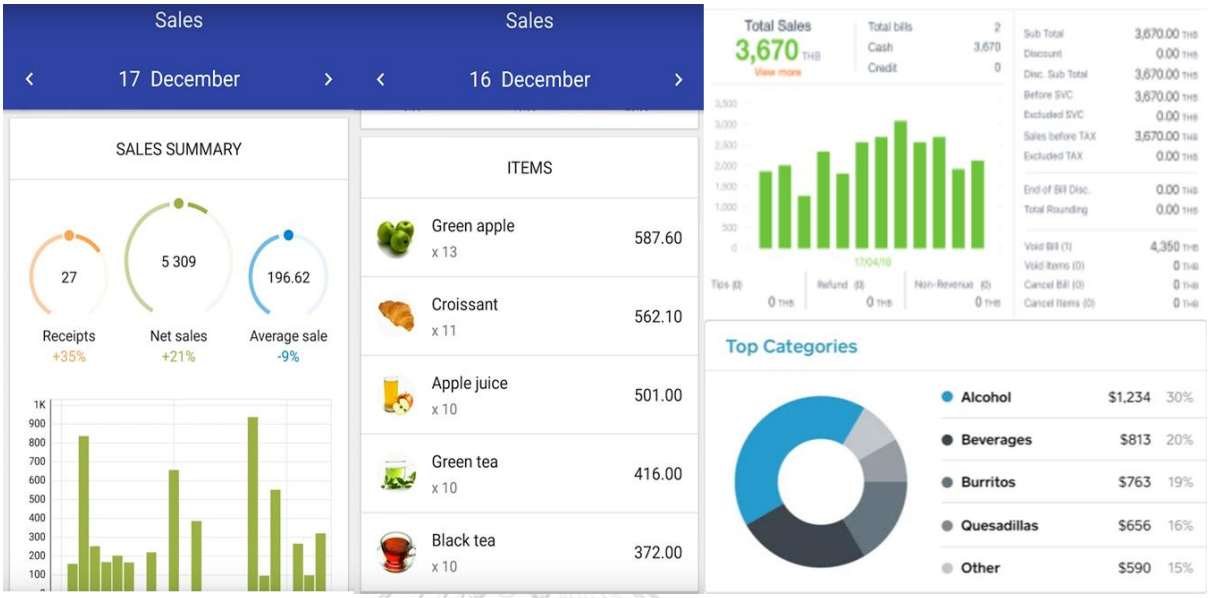


Figure 4 A Compilation of Various POS Dashboards

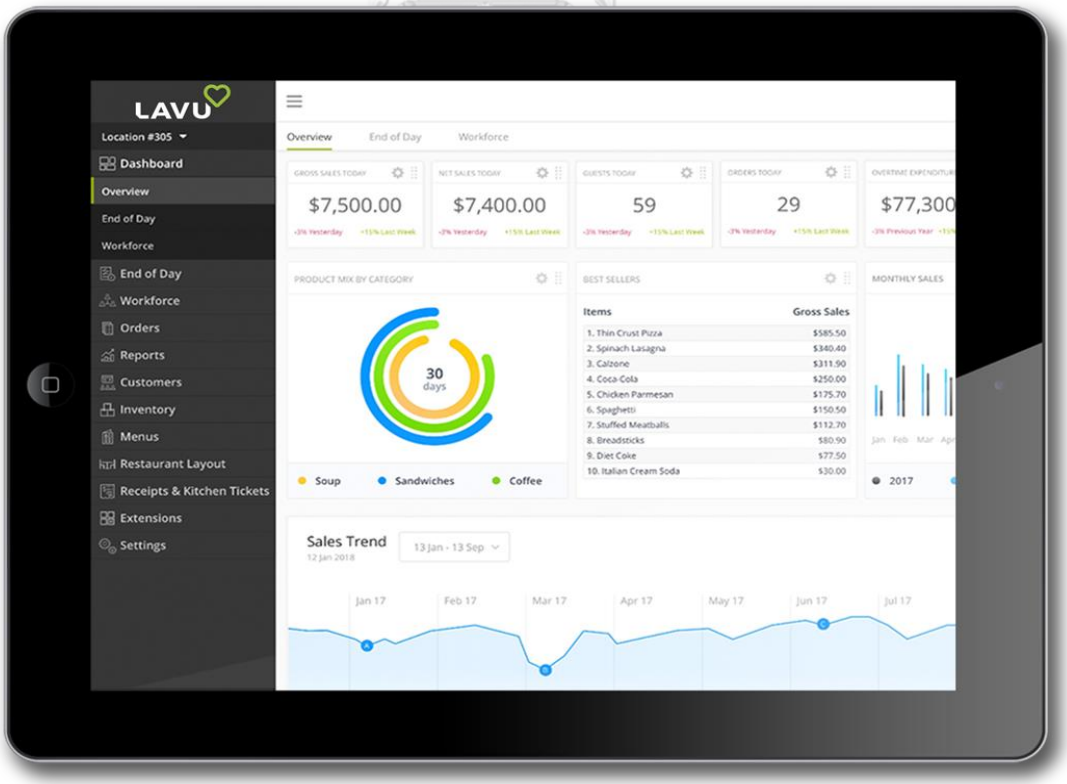


Figure 5 Lavu Dashboard

As shown in Figure 3, 4, and 5, the current dashboards of the company and competitors focus on showing sales figures and best-selling items. This information heavily focuses on financial performance. Restaurant owners know that there are other non-financial measures of restaurant performance but are unsure of what is important to look at in order to help them improve operations and grow their businesses. The increasing numbers of requests to know restaurant performance led the company to research on restaurant performance measures. The company found that there are numerous quantitative measures that can reflect performance in various aspects of restaurant management such as operations, inventory, anomaly detection, and etc. Moreover, the company's POS system collects data of different dimensions and levels such as number of customers, table assignment, meal duration, and etc. With these data, the POS can definitely create a more in-depth, multi-dimensional analyses than just sales summary.

Thus, there is a clear gap between what is currently available in POS dashboards and what is possible by the system and what is recommended by experts. This reveals an opportunity for the company to fulfill this need for restaurant performance measures by utilising the existing raw transactional POS data and turn them into important performance indicators. In order to deliver these insights and values to users in an effective way, a dashboard has been identified as an appropriate medium to do so. As a result, a redesign of the current dashboard becomes the company's product direction. The dashboard must contain information of interests and they must be presented in an easily understandable way for users to find it useful. The main questions to answer and outputs to deliver are presented in sections below.

1.2 Statement of Problems

The problems can be broken down into 3 parts:

- Which Key Performance Indicators (KPIs) should be selected to reflect restaurant performance?
- How to display the selected KPIs in a dashboard so that users find it useful and easy to interpret?
- How to transform POS transactional data and store them to display the selected KPIs?

1.3 Research Objectives

- To identify relevant and useful full-service restaurant's Key Performance Indicators (KPIs)
- To design a business intelligence dashboard for KPI visualisation
- To design data warehouse that is suitable for storage and retrieval of the selected KPIs

1.4 Scopes of Work

Restaurants

Restaurants as the target group of this research only refers to full-service, casual-dining restaurants which begin with customers sitting at a table, staff taking orders and serve food, and collecting payment at the end of the meal. KPIs and assumptions are based on this type of restaurants only. Thus, the outcome of this research might not be applicable to other types of restaurants such as quick-service, self-service, buffet, bars, and fine-dining.

Business Intelligence

Business intelligence refers only to the visualisation of data. The research does not cover advanced data analytics or predictive analysis.

Dashboard

The scope includes requirement analysis, designs, and evaluation of designs. Implementation is not in the scope as it would take a longer time to complete than this research duration.

1.5 Expected Benefits

The expected benefits of this research will be useful to two groups of people.

For the case-study company

- The KPI dashboard is a new feature that is not yet available in competitors' products, thus it would help to attract new customers.
- It will satisfy customers' needs of wanting to know their restaurant performance beyond sales number.
- It will lower customers' bargaining power to switch to another POS. This is because all historical data and analyses are already in the case-study company's database. Changing POS would mean customers losing all their valuable data.
- It will encourage real, consistent usage of the POS as KPI dashboard will only be valuable and correct if input data are valid and reflect real scenarios. If users input inconsistent data or use irregularly, KPI dashboard would not be useful.

For restaurant owners and managers

- They benefit from knowing the current and historical restaurant performance in multi-dimensional aspects of restaurant management.
- They are equipped with information and valuable insights that would be useful to make informed decisions on operations improvement and correction.
- They can monitor and track progresses in an objective and quantitative manner.

Chapter 2 Literature Review

2.1 Performance Measure in Restaurants

Performance measures help owners assess how well a restaurant is doing over time against its goals or in relation to other comparable restaurants. Operations in a restaurant include many processes such as ingredient sourcing, cooking, staffing, front-of-house services, inventory, marketing, and etc. Thus, there are many aspects to measure restaurant performance depending on which activities are considered. From researches for this thesis, there is no standard set of performance metrics for restaurants. A list of quantitative performance metrics of restaurants is consolidated from academic papers and industry experts and explained in section 2.1.1. Then, section 2.1.2 explains Balance Scorecard as a framework to select Key Performance Indicators (KPIs) for restaurants.

2.1.1 Restaurant Performance Metrics

This section explains an extensive list of performance metrics of restaurants. The list combines information from various sources including academic researches and industry experts' articles such as Ancill (2016), Kimes (2004), Alois (2017), Zeisig (2018), a published list of Top 25 Restaurant KPIs (eab group, 2011), and overseas POS software providers such as Square and Lavu.

The metrics are grouped into 3 types whose focuses are on different areas of interests, namely financial indicator, operations efficiency indicator, and lastly customer satisfaction indicator.

Financial Indicators

These metrics are related to the financial performance of a restaurant. They are concerned with revenue, costs, and profits.

Sales Numbers or Revenue

Sales numbers aggregate all sales amounts from paid bills occurred during a specified period of time. Examples are hourly, daily, weekly, monthly, sales-to-dates sales figures.

Sales = Sum of paid bills in a selected time period

Revenue per Available Seat Hour (RevPASH)

This measures the revenue on a per available seat hour basis. It is used in revenue management to analyse the efficiency in seating and selling food items to customers.

RevPASH = total revenue / (available seats x opening hours)

Revenue per Available Square Metre (RevPAM)

This measures the revenue achieved by the restaurant on a per square metre basis

RevPAM = total revenue / area of the restaurant in square metre

Revenue per Table

This measures average revenue per table in a given duration. This can be monitored on various time intervals such as daily or hourly depending on level of activity in order to make meaningful comparisons.

Revenue per Table = revenue / number of tables / unit of time

Average Check Size

This shows the average spending per unit which could be per bill or per customer. Different restaurant types would have different average check size. Depending on other factors such as meal duration, it has an implication on profitability of restaurants.

Average check size per customer = revenue / number of customers

Average check size per bill = revenue / number of bills

Food Loss Percentage

This measures unserved or thrown away amount of food as a percentage of total food produced. It is difficult to control as unserved food could be because of many uncontrollable reasons. Keeping this percentage low is desirable to maximise profit.

% Food loss = (volume of unserved food / total volume of food produced) x 100

Beverage Loss Percentage

Similar to food loss percentage, this is to assess the management of beverages in a restaurant.

% Beverage loss = (actual quantity of beverages in inventory / expected quantity of beverages in inventory) x100

Food Cost Percentage

This shows the percentage of food costs over food sales. Food cost percentage for all goods sold is calculated by dividing the total food costs by the total sales during a time period. However, in reality ingredients might not be strictly used as instructed in recipes; ingredients such as salt, pepper, and oil are almost impossible to quantify the cost for each dish. Instead, according to Tetreault (2017), inventory level can be used to conveniently calculate food cost percentage. The formula is as follows.

Food Cost Percentage = [(Beginning Inventory + Purchases - Ending Inventory) / Food Sales] x100

Knowing these financial numbers are insufficient to reflect operations efficiency and performance. They cannot be used to identify operational problems. The operations KPIs in the following section are more relevant to show how a restaurant performs on a day-to-day basis.

Operations Efficiency Indicators

Below set of KPIs focuses on operations-related performance where capacity and resource utilisation, including labour, table, and ingredients, are concerned to measure productivity and efficiency of front-of-house operations.

Number of Customers

Number of customers reflects the number of patrons who eat at a restaurant in a selected time period. It can be used to compare with number of items ordered to check how many customers in a table order and contribute to sales i.e. average check size per customer.

Number of customers = Sum of all people who eat at a restaurant in a time period

Average Meal Duration

This represents how long customers spend time at a table for the complete duration of a meal. It can be measured in different time periods such as for lunch, dinner, and breakfast to help plan restaurant operations at different times. This affects the turnover rate, seating occupancy, and subsequently profitability of a restaurant.

Average meal duration = sum of meal duration / total number of covers

Table Turnover

This shows the number of covers that are served during a time period divided by number of all available tables. Ideally, table turnover is preferred to be high as it means

that restaurants can accept more new customers to be seated at a table, thus generating more sales.

Table turnover = number of covers in a selected time period / number of tables

Table Occupancy Rate

It shows how many percentage of tables is occupied at a given time.

Table occupancy = (actual number of occupied tables / total available tables) x 100

Number of Guests per Table or Bill

This measures the average number of customers per table or bill. It is used to calculate average check per table or customer to see if an individual customer is contributing sufficiently to sales.

Number of guests per table or bill = total number of guests / total number of bills

Number of Tables Served per Waiter

It measures the average number of tables served by one waiter in a period of time. This could indicate if one waiter is covering a reasonable amount of tables to maintain a good level of service. Exceeding a threshold might indicate that additional waiter is needed.

Number of tables served per waiter = Number of tables served / Number of waiters in a given period

Percentage of Front-of-House Labour

This is to assess labour productivity as compared to value of sales. It needs constant monitoring to be able to measure this accurately.

% Front of house labour = (number of hours of front-of-house work / Total work time in hour) x 100

Percentage of Unavailability of Menu Items

This shows the percentage of unfulfilled orders over total orders. This show how often items are run out which could be due to poor inventory management or unexpected changes in demand. This could cause potential revenue loss and lower customer satisfaction.

% Unavailability = (Unavailable orders / Total orders) x 100

Customer Satisfaction Indicators

The KPIs below measure customer satisfaction level of food and service quality of restaurants, hence they are a proxy to reflect the quality of service, which is a critical factor in running a successful restaurant.

Number of complaints

This tracks negative customer feedback of food and services.

Number of complaints = sum of complaints in a period of time

Percentage of Customers Satisfied with the Time to Be Served

This is highly based on subjectivity and collection of data might not be accurate. Nonetheless, it shows the percentage of customers that express satisfaction about serving time.

% Customers satisfied with the time to be served = (Number of customers with positive feedback on serving time / total customers) x 100

Percentage of Tips from Total Collected

This is a proxy to measure customer satisfaction as customers who are satisfied tend to leave tips.

% Tips = (amount of tips / total bill amount) x 100

Percentage of Positive Feedback from Customers

This tracks positive customer feedback of food and services.

% Positive feedback = (# Customers giving positive feedback / # Customers giving feedback) x 100

Percentage of Reserved Table

This is a measure of restaurant attractiveness as customers intentionally book in advance to avoid missing a table. This indicator helps in operations as well by helping managers allocate tables for reservations and walk-ins more effectively.

% Reserved table = (Number of tables occupied with reservation / Number of tables occupied) x 100

Percentage of Cancelled Reservation

This measures the percentage of cancelled reservation from total reservations. It indicates the loss of potential revenue. Also, it helps managers to optimise occupancy by table reallocation.

% Cancelled reservation = (number of cancelled reservations / number of total reservations) x 100

Top selling food item and food category

This shows the top performing food items or categories. It can be more specific such as top 3 lunch menus or top 5 drinks. This could have implications on inventory preparation in order to match with demand and ensure that there is no unavailable item.

As seen above, there are many performance metrics but not all are equally important. It depends on what users would like to focus on and how often they would like to monitor these numbers. Establishing a well-categorised and holistic set of KPIs requires a well-defined methodology and considering different dimensions of performance (Ghazisaeidi et al., 2015). In the next section, a well-known framework, Balanced Scorecard, is explored to select a set of KPIs to align with a restaurant's vision and strategy.

2.1.2 Balanced Scorecard for Restaurants

KPIs provide the foundation for performance management. They help track progress against predefined targets or benchmarks and compare performance over time or against other organisations. Several models and frameworks for categorising performance measures and KPIs are available such as the Performance measurement matrix, the Performance pyramid, the Balanced Scorecard (BSC), and the Performance Prism (Ghazisaeidi et al., 2015). BSC is a comprehensive set of performance measures that focus on a company's current position and future visions. The objective of the BSC is to provide a more balanced view of a firm's performance based on 4 perspectives which are financial, customer, internal business process, and learning and growth (Kaplan & Norton, 1992). BSC provides guidelines to select KPIs that are aligned with organisation's goals and help organisation translate strategy and vision into actions.

There are several performance measure researches on restaurants that adopted Balanced Scorecard (BSC) to build a well-balanced set of KPIs. Liu and Chen (2013)

explored the use of BSC to measure performance of 3 buffet restaurants in Taiwan. BSC was chosen because it takes into account non-financial performance which is critical in service industry. Abdillah and Diana (2018) also adopted BSC in developing a balanced scorecard for restaurants and concluded that BSC model can help the management create strategies to improve restaurant performance. These researches have yielded good results and thus, proving that BSC is a good measurement framework for dashboard systems. The resultant set of KPIs of restaurants based on BSC from Liu and Chen (2013), and Abdillah and Diana (2018) are summarised below.

Financial Perspective

The financial perspective looks at the profitability in monetary terms and profitability is linked to increasing revenues, reducing costs, and maximising asset utilisation.

- Revenue growth: sales, profit margin
- Cost reduction: waste cost control, lower working capital, food cost
- Asset use: RevPASH, return on investment, return on human resource

Customer Perspective

The customer perspective includes several measures such as customer satisfaction, customer retention and loyalty through customer value and customer profitability (Kaplan & Norton, 2001).

- Total customers
- Retention: ratio of customer return
- Acquisition: ratio of increasing new customers
- Satisfaction: average check per bill, average number of customers per waiter, frequency of customer complaints

Internal Business Process

The internal business process perspective measures performance of the key processes in the organisation that can be optimised and improved to attract and retain customers (Abdillah and Diana, 2018). Examples of operations management process include the process of receiving orders, and working until sending products to customers. The time taken to complete is a reflection of effectiveness and efficiency of these processes.

- Front operations: time taken to seat, order, serve, cooking duration, cover per labour hour
- Inventory: inventory turnover rate
- Kitchen: food loss

Learning and Growth Perspective

The last perspective is to build infrastructure or prepare resources and knowledge to achieve other three perspectives. It concerns generating long-term growth and improvement to the organization. It measures the following areas: employee capabilities, information system capabilities, motivation, empowerment, and alignment (Kaplan and Norton, 1996).

- Completion ratio for employee training programs
- Average hour for employees on-the-job training
- Turnover rate for core employees & part-time employees
- Attendance rate

Even though the KPIs above are not specifically meant for full-service restaurants, they still provide a reliable framework to follow when selecting KPIs for full-service restaurants in this thesis. As shown above, there is a myriad of quantitative measures on restaurant performance. Based on BSC, they can be grouped into 4 perspectives and form a well-rounded set of KPIs for restaurants. The KPIs are important to know the current status

and work toward a restaurant's goals. Next section explores how to build a business intelligence system.

2.2 Business Intelligence System

After KPIs are selected, they must be presented in an effective way to the audience. Hence, business intelligence system must be developed in order to make sure that necessary data are collected and manipulated in a way that can be used to visualise KPI information on a dashboard display.

According to Gartner (2018), Business Intelligence (BI) is a general term that refers to the applications, infrastructure and tools, and best practices that enable access to and analysis of information to improve and optimise decisions and performance. BI systems are meant to provide adequate and reliable up-to-date information on different aspects of enterprise activities (Olszak and Ziemba, 2007). The transformation of data into information and knowledge enables users to make informed decision making, strategic thinking, and action plans to improve business performance.

Building and implementing BI systems require a systematic approach. Several literatures such as Gangadharan and Swami (2004), and Olszak and Ziemba (2007) outline similar sets of steps to build BI systems. They are summarised into five steps of BI system development.

2.2.1 Analysis

Requirement Analysis is performed to find out which present and future business questions need answers, who will be using the system, which key performance indicators they are looking for (Gangadharan and Swami, 2004). The analysis stage

produces objectives and overview design of the system including the sources of data, feasibility, resource requirements, and timeline.

2.2.2 Designing

After requirements are clearly defined, necessary data are located in the existing transactional database. Traditional data storage is OLTP (Online Transactional Processing) which stores data using relational database model. This relational model is suitable for storing transactional data such as individual sales records, thus it is used as a good design solution for transactional systems because of its ease of adding, finding, and updating like the one used in POS. However, these data are scattered in multiple tables and such a storage model is not suitable for report generation and complex data queries.

A new database of different structures must be designed for storing historical data of interests from different sources. The new data warehouse uses OLAP (On-Line Analytical Processing) techniques to replace OLTP to achieve fast retrieval and reporting for BI purposes.

BI system can only be useful if a dashboard is present to display information to users. Thus, a dashboard display must be designed carefully to ensure that data representation can be easily understood by end users and that all their requirements are fulfilled.

2.2.3 Development

Depending on the data requirements and database structure determined in the previous stage, an Extract-Transform-Load (ETL) is performed on the existing data to pull required data, turn them into the needed formats, and then store them in the new

database. The extraction phase inspects the original sets of data and checks whether they are valid and in the right format. Then, transformation phase is made of rules and formulae that turn the original data into the desired format, for example, summing a day's transactions into a single aggregated value. It transforms raw data into something relevant to the business requirements. Lastly, the loading of data into the new database can be scheduled to run at certain intervals such as hourly, daily, weekly, depending on business needs.

2.2.4 Deployment

After developing and testing for the correctness of information and reliability of the system, BI system would be ready to be deployed into production. In order to ensure the success of BI system, end user training and support are necessary (Gangadharan and Swami, 2004). Users are to verify if deployed version serves their needs effectively. Developers need to monitor how users interact with the system and note if things are working properly or need adjustments.

2.2.5 Evolution

Feedbacks are collected from users to measure the success of the BI system. Adding more advanced analyses and increasing cross-functional information sharing are objectives of evolution stage (Gangadharan and Swami, 2004).

Iterations of the above stages are expected to continue to add new analyses as required by the business. In this research, the focus is on the first 2 stages which are Analysis

and Designing. Section 2.3 and 2.4 below dive into the Designing stages of the dashboard display and data warehouse and for BI system respectively.

2.3 Dashboard for BI System

One critical component of BI system is the dashboard where visualisation takes place to provide users with useful information. In order to do so, the framework of dashboard design is explained in section 2.3.1. Then, visual perception is studied in section 2.3.2 to ensure that the display design would be effective in communicating information to users. Next in section 2.3.3, different types of data relationship are studied to understand how insights can be created by providing contextual information and comparison to promote critical analysis. Lastly, display media for different data relationships are identified to ensure that visualisation is effective in portraying information and insights correctly to users.

2.3.1 Dashboard Design

Few (2006), one of the well-known academics in the area of data visualisation defined a dashboard as a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance. Yigitbasioglu and Velcu (2012) gave a similar definition of dashboard as “a visual and interactive performance management tool that displays on a single screen the most important information needed to achieve one or several individual and/or organisational goals, allowing the user to identify, explore, and communicate problem areas that need corrective action”. Both definitions highlight the following characteristics of a dashboard:

- Visualisation of important data
- Display on a single screen

- To achieve certain objectives
- For a group of users

Eckerson (2006) classified dashboards into three types based on the intended use.

- Strategic dashboard - It displays high-level measures of performance and often some kinds forecast, mainly used by executives to monitor the health and opportunities of the business.
- Analytical dashboard - It displays information, often in forms of comparison or extensive history or rich context. The purpose is to see beyond what is going on to identify the causes or anomalies. This type of dashboard is used by manager level to analyse for improvement.
- Operational dashboard - It displays specific information that often requires immediate attention. Usually alerts will result in corrective actions.

Existing researches on dashboards mainly focus on technical issues and implementation. For this research, only researches related the selection of KPIs and dashboard designs are focused. Implementation and technical details are omitted as they are irrelevant to the scope of this research. Most case studies are from the field of manufacturing industry where dashboards are commonly used in shop floor operations and healthcare industry where several types of dashboards have been developed to improve operations and decision making in operating rooms, emergency department, and radiology department.

Vilarinho, Lopes and Sousa (2017) provided a design process for a dashboard by adapting the design process from the traditional product development process and claimed that it can be applied by other industries with the same objectives. Using the process in Figure 6 below, they designed a dashboard to improve the performance of productive equipment and processes at the shop floor level. The 5-step process is shown below in Figure 6.

Figure 6 The 5-step Process to Design a Dashboard

Explanation of each stage is presented below.

1. Diagnosis stage includes selection of stakeholders and information gathering through dialogues, interviews and feedback.
2. Requirements refer to the identification of dashboard objectives, target users, functional and visual characteristics, contents and support in decision making. The knowledge used is from literature and experts' opinions and suggestions from the diagnosis stage.
3. Development of a dashboard template include changing business needs into technical requirements. At this phase, a mock-up should be designed and share with stakeholders to receive feedback. Selected metrics should be shown in the mock-up.
4. Assuring the necessary resources make certain that necessary data are available in the right format and easily accessible to be used for calculation and display.
5. Implementation, evaluation, and improvement is the last stage where actual implementation happens. Once the dashboard is in operations, its effectiveness must be evaluated.

Tokola et al. (2016) followed a similar process as above to design a manufacturing dashboard. They focused on stage 2 where an exploratory survey was conducted to get

requirements from different groups of users in order to design dashboards that were suitable for each group. They concluded that different levels of users had different set of desired KPIs, the frequency at which they wanted to view the dashboard also differed by how frequent they could make changes. In their research, three designs were made. Workers needed operational dashboard where near real-time status and alerts of machine were the focus to result in immediate detection and corrective actions. Meanwhile, tactical dashboard was for production managers whose focus was to monitor the utilisation of resources and improve efficiency. Lastly, strategic dashboard was designed for executives to show forecasts and high-level performance measurements in several areas such as productivity, costs, inventory, and etc.

Apart from manufacturing sector, another industry that has several academic publications on dashboard design and development is the healthcare sector. The focus is also on the selection of appropriate KPIs. Karami (2014) and Wakai et al. (2013) adopted the Delphi technique to select a set of KPIs for radiology and emergency department respectively. A more theoretical method was done by Safdari et al. (2014) who created a set of KPIs based on BSC and analytical hierarchical process framework in order to develop a dashboard for emergency department. In all above researches, the focus has been on requirement gathering and KPI selection. However, selected KPIs were put onto a dashboard without much reference to the principle of visualisation.

The information must be communicated through proper visual designs on a dashboard. Hence, the visual design of dashboard plays a critical role in ensuring that target audience interpret and easily understand the right message. KPIs have meaningful messages needed to be conveyed effectively to users. Zelazny (2001) proposed a 3-step process used to determine the appropriate display media as follows:

1. Determine the message – data and measures can be expressed in many forms such as percentage, baht, sales, profits, and etc. In order to identify which

forms, it depends on the intended messages to the users. Chart types will depend on the messages.

2. Identify the comparison – Zelazny (2001) stated that any message will lead to one of the five basic kinds of comparison, namely component, item, time series, frequency distribution, and correlation. This will be explained in greater details in section 2.3.3.
3. Select the chart form – Zelazny (2001) simplified the number of chart forms into five which are pie chart, bar chart, column chart, line chart, and dot chart to correspond to the five basic comparison types above. More elaboration is done in section 2.3.3.

The next sections explore principles of visual design, focusing on visual perception for fast processing and interpretation of data, and followed by the guidelines to select an appropriate visual medium in order to effectively convey the intended messages.

2.3.2 Visual Perception

Visual communication is critical in conveying the information effectively to users. Hence, the use of visual components such as colours, marks, and shape, must be a deliberate choice to make sure that the dashboard effectively does its job. The design must be easy to perceive and interpret in order to make sense of information or grab attention in case of alerts or anomaly detection. This can be achieved by adopting pre-attentive visual properties that facilitate processing of information in spatial memory without consciousness at an extremely high speed, thus taking less effort in digesting information. Pre-attentive attributes are important in visualisation because it can determine what information catches users' attention. Ware (2004) suggested 4 categories of pre-attentive visual properties, namely colour, form, spatial position, and movement. Each category is explained in detailed below.

Colour

Colour can be described using HSL (Hue, Saturation, and lightness). Hue is a more proper term to refer to colours such as red, green, yellow, etc. Saturation is the extent a particular hue shows its full essence as shown in Figure 7 below. Lightness is the degree of darkness or brightness a hue appears from fully black to fully light as shown in Figure 8 below (Few,2006).

Figure 7 Saturation (Few, 2006)

Figure 8 Lightness (Few, 2006)

Hues, saturation, and lightness are pre-attentively processed and can be used to separate visual elements from their environments. Few (2006) cautioned that colour must be used with a full awareness of the surroundings because humans perceive a colour as relative to its surrounding. A pixel with the same hue and intensity could be viewed differently when it is on different background colours. Few (2006) presented an example of a word 'Text' which had the same hue but was put on two different background colours can be perceived as different as shown in Figure 9 below.

Figure 9 Context Affecting Colour Perception (Few, 2006)

Few (2006) suggested that vivid colours should only be used when highlighting special cases that require attention while soft colours should be standard set of colours for dashboard. This is because fully saturated, bold colours and light, subtle colours convey an entirely different meaning. In addition, subtle colours allow users to view dashboards with calm and open mind instead of being bombarded with vivid colours. Figure 10 below shows 2 different sets of colours which should be used for different purposes. The ones on the left show subtle standard colours that should be used predominantly in dashboard while those on the right should only be used to highlight alerts.

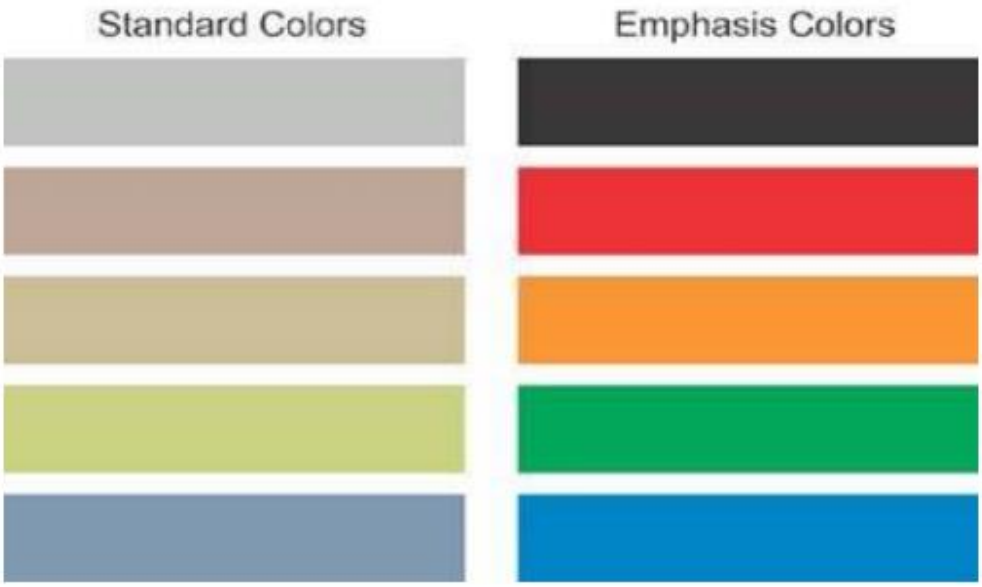


Figure 10 Example of 2 Sets of Colours: Subtle and Vivid (Few, 2006)

Form

According to Ware (2004), form refers to a set of attributes that can be manipulated to increase or reduce attentions to a member of data set. Figure 11 below illustrates the effect of each attribute.

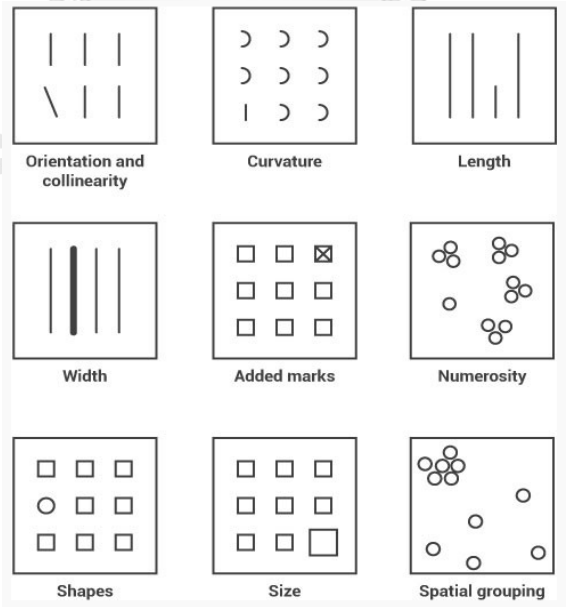


Figure 11 Examples of Form Attributes (Interaction Design Foundation, 2018)

Few (2006) explained that the attribute of length is good for displaying quantitative values in the form of bar or line graphs. Another useful attribute is size which can signify relative importance in dashboard. Added marks are useful for alerting on information that require user attention.

In addition to the above attributes, Few (2006) also added enclosure as another powerful attribute for grouping sections of data or highlighting important content. Enclosure can be in the form of line border or a colour fill behind the content as shown in Figure 12 below.

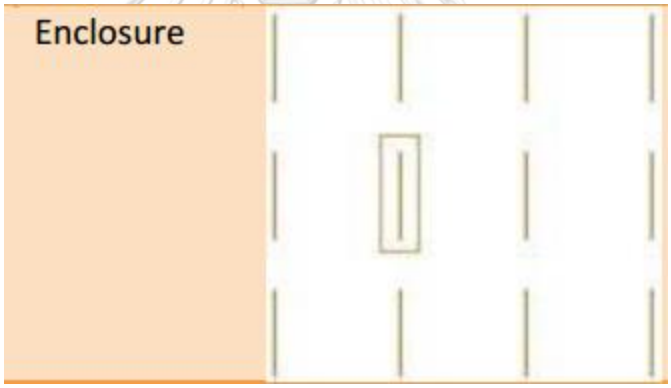


Figure 12 Enclosure (Few, 2006)

Spatial positioning

There are several ways to present spatial positioning as proposed by Ware (2004). However, In the context of dashboard design, Few (2006) only selected 2-D positioning as relevant to dashboard display as shown in Figure 13 below. It is effective in presenting quantitative data in graphs because the difference in 2-D position is intuitive to spot and processed visually.

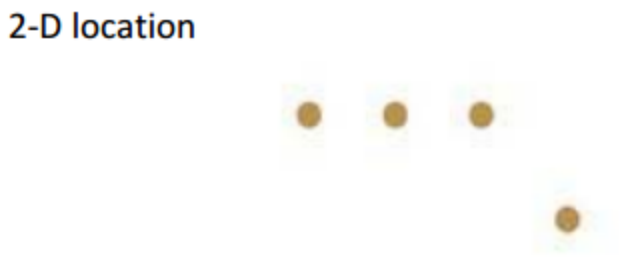


Figure 13 2-D Positioning (Few, 2006)

Movement or Motion

Flicker is a great attention-drawer. It can be effective in alerting a piece of information that needs immediate attention. However, both Ware (2004) and Few (2006) gave cautions that when using flicker, it could be annoying and distracting for users to absorb the rest of the dashboard. Also, overuse could lead to desensitisation and thus reduced effectiveness. Hence, movement must be used sparingly only when needed.

Each of these pre-attentive attributes has its own purpose and limitations. Few (2006) highlighted that some might only be useful in representing either quantitative or categorical data. For example, shapes or hues signify different categories but cannot be used to quantify measures. There are also limits to how much humans can distinguish between varieties within an attribute. For example, showing 5 levels of saturation of the same hue is not appropriate as it is hard to differentiate between them as shown in Figure 14 below. Thus, designers of dashboard must be aware of the strengths and limitation of attributes and human capability in order to employ suitable attributes for maximum effectiveness.

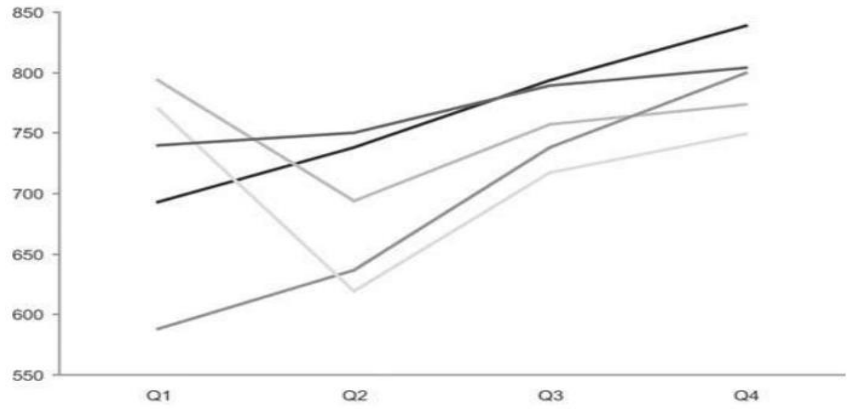


Figure 14 Example of Excessive Levels of Saturation Reducing Readability (Few, 2006)

2.3.3 Data Relationships and Types of Display Media

Selecting the right type of medium for a certain set of data is critical to ensure that information can be perceived easily and correctly by users. Providing context to a set of data also helps enrich the understanding and create insights to user. Thus, in order to choose the suitable and effective type of display media, it is important to first understand data relationships. This is because each medium is more suitable for conveying certain types of relationship. Below lists 7 types of data relationships that are useful in business analysis (Few, 2004). They include those proposed by Zelazny (2001) as well.

1. Nominal Comparison – a simple comparison of the quantitative values of subcategories.
2. Time-Series – shows changes in values of the same metric over time. It is great for showing trends over time.
3. Correlation – is used if a dataset has two or more variables that may demonstrate a positive or negative correlation with each other.

4. Ranking – shows how two or more values relate to each other in relative magnitude.
5. Deviation – explores if any data point differs significantly from the mean, highlighting anomalies.
6. Distribution – shows data distribution often surrounding a central value.
7. Part-to-Whole – shows a subset of data as compare to the larger whole.

These data relationships are used in making analysis such as comparison, error detection, trend detection which are critical elements in making decisions. In order to display these relationships clearly to users, certain types of display media are more suitable than others. Using inappropriate medium might result in failure to show these relationships and wrong interpretation. Suitable media facilitate data digestion and understanding. Below summarises common display media used in dashboards and guidelines to use them effectively based on several researches and online publications such as Few (2006) and Oetting (2018).

Bar Chart

Few (2006) explained that bar graph is suitable for representing discrete set of data along nominal or ordinal scale. Values can be compared by looking at the height or length of each bar while exact amount can also be derived from the axis. They can be horizontal or vertical, each has its own advantages in term of readability.

Pie Chart

Pie charts are best used for making part-to-whole comparisons with discrete or continuous data. A pie chart represents numbers in percentages, and the total sum of all segments needs to equal 100%. Cautions must be taken when visualising with pie chart as angles are hard to see if differences between segments are small (Few, 2006).

Line Chart

Line charts are used to show time-series relationships with continuous data. They help show trend, acceleration, deceleration, and volatility of data. In contrast to bar charts, line is appropriate for representing continuous data set along an interval or quantitative scale (Few, 2006; Oetting, 2018). Line charts focus on the overall shape or progress or trend of values and where individual values are not emphasised (Few, 2006). Oetting (2018) cautioned that lines should be solid and number of lines in a single chart should not exceed 4. Unlike bar charts, line charts need not start from 0, the scale can be enlarged to see greater details of data.

Sparklines

Data visualization expert Tufte (1983) invented the sparklines to condense historical trend leading up to the current measure, providing useful context in very little space. This is ideal in the context of dashboard design where sometimes individual values are not as important as visualising context and trend. It is often used together with a discrete number. As shown below in Figure 15, it provides a richer context to viewers to interpret the number in a more analytical way.

Figure 15 Sparklines

Area Chart

Area charts are similar to line charts in depicting a time-series relationship, but they can also represent volume.

Scatter Plots

Scatter plots show the relationship between items based on two sets of variables. They are best used to show correlation in a large amount of data.

Icon

Alerts are used to flag information as important or in need of attention. Variations of colour indicate different degrees of importance or urgency.

In short, visual perception and appropriate media are critical and must be carefully considered in order to ensure that messages on the dashboard are conveyed to users correctly and effectively. Applying these principles together make for an easily understandable and useful dashboard. After KPI selection and dashboard design has been done, the requirement for data would be ready to design a data warehouse. Next section discusses how a data warehouse is designed for business intelligence system.

2.4 Data Warehouse for BI System

In relational database or OLTP database, data are structured and stored in such a way that optimises adding, updating, and deleting of data in a real-time operational database. Normalisation is a technique used to design relational database and ER diagram is used to illustrate relationships between tables. However, for business intelligence system, the main purpose is to retrieve data as fast as possible and that requires data warehousing. Data warehouse architecture uses a different method to store data in such a way that facilitates the searching, retrieving, and reporting of quantitative values. Dimensional modelling is used to design data warehouse.

According to Kimball and Ross (2013), there are 4 steps to dimensional modelling design process:

1. Select the business process
2. Declare the grain
3. Identify the dimensions
4. Identify the facts

In addition to the steps above, business needs and availability of data from current data sources need to be taken into consideration to ensure that the design is practical and possible to implement. Section 2.4.1 explains the elements of dimensional modelling that are necessary to complete the 4 design steps.

2.4.1 Elements of Dimensional Modelling

Granularity or grain is the lowest level of information that is needed to be captured in order to answer business requirements. Atomic grain is the lowest level at which data is captured by a given business process. It is useful to consider using the atomic grain in order to handle all user queries (Kimball and Ross, 2013). The lower the level of grain, the larger the size of data warehouse. Thus, user requirements play an important role in determining the appropriate level of grain.

A **fact** is a numerical measurement or metric of interest from a business process that can be summed, averaged, or manipulated. A fact table must be linked to a physical observable event, not to the requirement of a particular report (Kimball and Ross, 2013). Facts and grains must be consistent.

A **dimension** contains descriptive categories that provide context of a business process. It is used to provide structure when filtering, grouping, and labelling for reporting

purposes. An attribute is a characteristic of a dimension. For example, year is an attribute in the date dimension while minute is an attribute in time dimension.

A **hierarchy** is a many-to-one relationship between members of a dimension or between dimensions. It is a conceptual representation of the hierarchies of their occurrences in the real world (Schneider, 2008). For example, one possible hierarchy of location dimension could be country > region > state > town.

A **dimension table** contains attributes which are characteristics of the dimension. A dimension table typically has two types of columns, primary keys to link to fact tables and descriptive data. For example, a staff dimension table contains attributes such as staff ID (a primary key), name (descriptive), and gender (descriptive).

A **fact table** is a table that contains the quantitative measure of interest at the appropriate granularity and dimensions that are associated with the measure. Kimball and Ross (2013) stressed that the design of a fact table must be based on an actual physical activity, and should not be influenced by the reports. Fact tables are the primary target of calculation and computation from queries users make (Kimball and Ross, 2013). The granularity of data in fact tables is determined structurally by the lowest level of granularity of each dimension table. Dimensions in the fact table are represented and linked to the corresponding dimension tables by dimension foreign keys. Thus, every dimension is linked to a fact table via foreign keys.

An example of a fact table and dimension tables and how they are linked is shown below in Figure 16. The business process is a sales transaction. The granularity is at day level and product ID level which are determined by the lowest level in Time and Product dimension respectively. This implies that the sales measurement in the fact table is a sum of 1-day worth of sales of each product. Here a fact table contains sales in dollar as

a numerical metric of interest. There are three dimensions which are product, time, and store. They are linked to the fact table via foreign keys, indicated as '(FK)' in Figure 16.

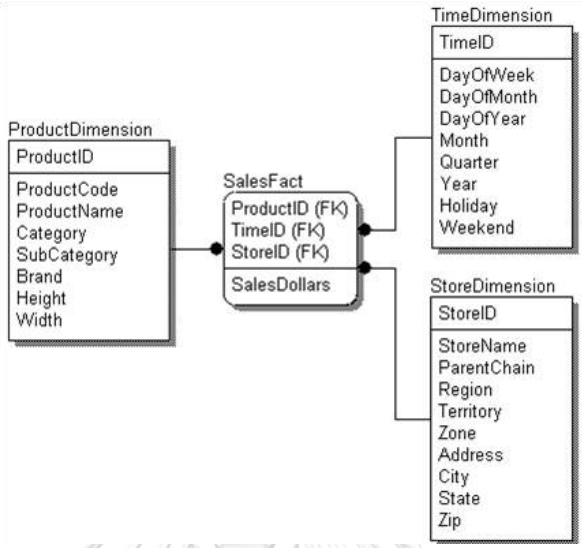


Figure 16 Example of Dimensional Modelling using Star Schema (Tayal, 2012)

After these elements have been defined, the relationships among these data are demonstrated through a schema which describes the structure of a data warehouse as discussed below in section 2.4.2.

2.4.2 Data Warehouse Schema

Schema is the database structure of the data warehouse. The design of data warehouse schema is aimed to enable fast retrieval and manipulation of data. Three commonly used architectures are explained below.

Star schema

The center of the star schema is the fact table which connects to other dimension tables via foreign keys as shown in Figure 16 above. Each dimension is separated and has its own table. All hierarchies are contained in the individual dimension tables without the

need to separate into hierarchical dimension tables. This reduces the number of join operation which slows down the retrieval time. All measures in the fact table have relationship with the connected dimensions and all have the same level of grain (Kimball and Ross, 2013).

Snowflake schema

The snowflake schema is an extension of the star schema. In this schema, each dimension is normalised and connected to more dimension tables. In essence, dimension tables are broken into hierarchies. Normalisation is not good for searching and retrieval as it makes queries more complicated and join operation takes longer time. Figure 17 shows an example of a snowflake schema where several dimensions such as Shop is normalised to city and then region, going up the hierarchy of location.

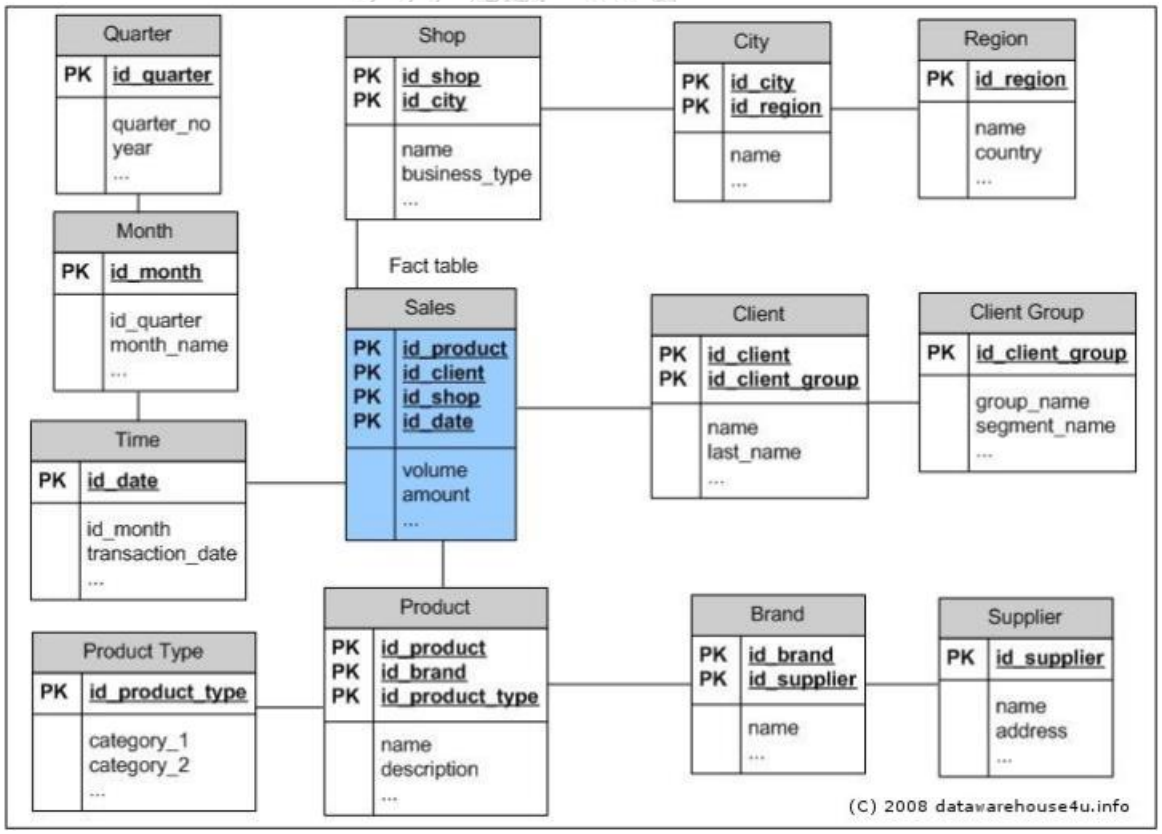


Figure 17 Example of Snowflake Schema (datawarehouse4u, 2008a)

Fact Constellation schema

A fact constellation can have multiple fact tables that share many dimension tables as shown in Figure 18 below where there are 2 fact tables, Sales and Delivery. This type of schema can be viewed as a collection of stars and hence is called a galaxy schema or a fact constellation.

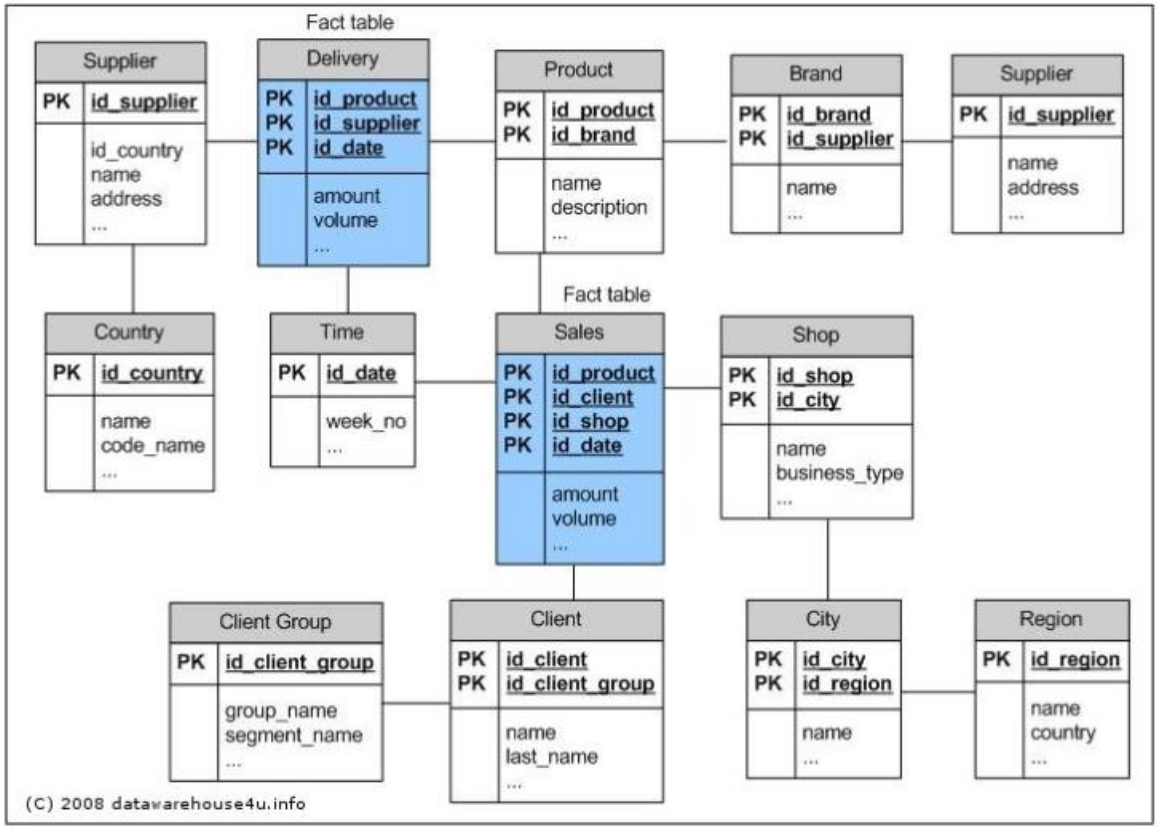


Figure 18 Example of Fact Constellation Schema (datawarehouse4u, 2008b)

2.4.3 Levels of Dimensional Modelling

There are 3 levels of dimensional modelling. Each level defines more details on the schema, making it more difficult to make changes going down each level as it is closer

to actual implementation. A summary of what is required in each level is shown in Figure 19 below.

Feature	Conceptual	Logical	Physical
Entity Names	✓	✓	
Entity Relationships	✓	✓	
Attributes		✓	
Primary Keys		✓	✓
Foreign Keys		✓	✓
Table Names			✓
Column Names			✓
Column Data Types			✓

Figure 19 Comparison of Three Levels of Dimensional Modelling (1keydata, 2019)

First, conceptual modelling is a high-level design showing different entities and their relationships as shown in Figure 20 below. The conceptual model is used to validate assumptions and design with business users in order to make sure that these datasets will be able to answer business questions and requirements. Changes are easily made at this stage. Iterations are done to verify that appropriate entities and their relationships are correctly determined before moving to the next level.

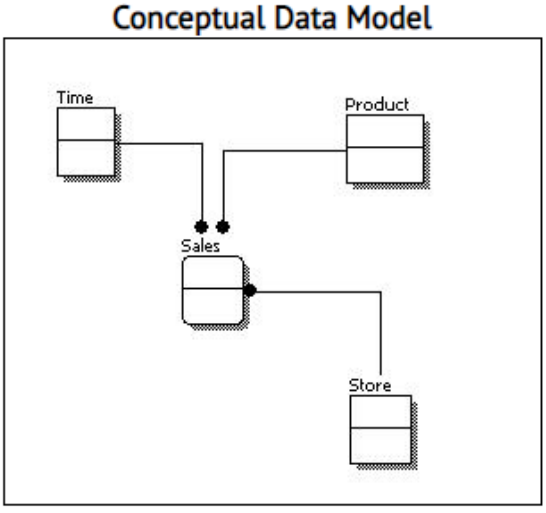


Figure 20 Conceptual Data Model (1keydata, 2019)

After conceptual modelling is designed, logical modelling is done to determine the details of entities such as attributes, primary keys, and foreign keys. Relationships between entities are clearly defined by primary keys and foreign keys as shown in Figure 21 below. At this stage, attributes need to be thought of carefully to make sure that they include all required information. The design needs to ensure that these data can be found or derived from data in the original relational database.

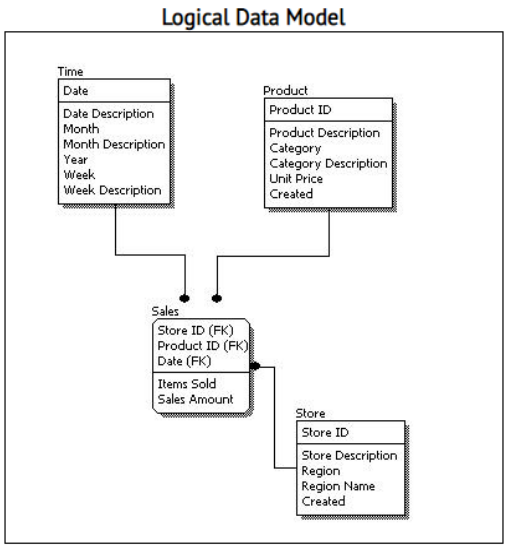


Figure 21 Logical Data Model (1keydata, 2019)

Lastly, physical data model is done to describe the exact implementation that is specific to the database of choice as shown in Figure 22 below. It contains specifications of all tables and columns. Column data types are also defined at this stage. After the physical data model is done, the designing stage of the data warehouse as part of the BI system is considered as done and ready for implementation.

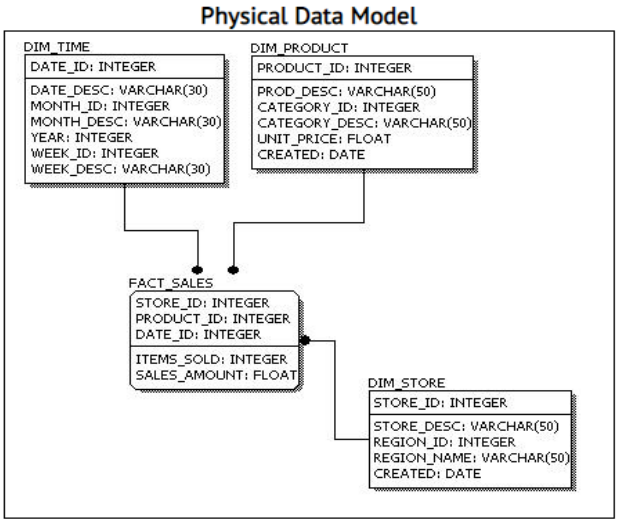


Figure 22 Physical Data Model (1keydata, 2019)

Literature review explores 4 main areas to design the business intelligence system for restaurants. It starts with the selection process of performance measures to become KPIs using Balanced Scorecard as a framework. Next, the steps to build a business intelligence system is discussed and then zoomed into individual components namely the dashboard and the data warehouse. Dashboard design is concerned with the choosing the right medium to visualise data and representing information in an easily understandable way for users to interpret easily and correctly. Lastly, literatures on data warehouse provide a well-defined process to design a data warehouse for BI system. Applying all these design principles, implementation is explained in details in the next chapter.

Chapter 3 Methodology

For the scope of this research, the approach to develop a BI system for restaurants follows the first 2 steps (Analysis and Designing) of the 5 steps proposed by Gangadharan and Swami (2004), and Olszak and Ziemba (2007) as summarised in section 2.2. In section 3.1, requirement analysis was done through qualitative feedback gathering from current customers and also business requirements from the case-study management team. Next, the designing stage is divided into 3 parts namely, KPI selection, design of dashboard display, and design of data warehouse. Section 3.2 explains the KPI selection process based on Balanced Scorecard and system limitation to finalise the list. Then, section 3.3 demonstrates the analysis of data relationship of the selected KPIs and matching of data types with appropriate media. The principle of visual perception by Ware (2004) and Few (2006) is applied to come up with the design of dashboard display. Next, section 3.4 goes through the steps to define elements of dimensional design process by Kimball and Ross (2013) and deliver the physical schema of data warehouse. Lastly, section 3.5 explains how the new dashboard design would be evaluated by current users. A summary of the research workflow, methodology, and output is shown in Figure 23 below.

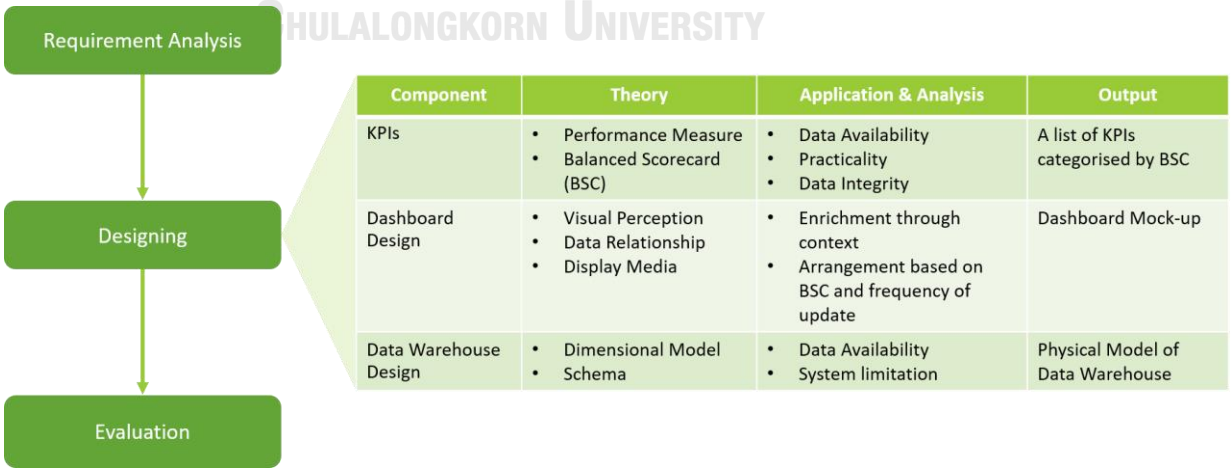


Figure 23 Summary of Research Methodology

3.1 Requirement Analysis

As a start-up, short time to market is critical to ensure that the case-study company stays ahead of competition. Compared with conventional surveys and focus groups, making use of existing data and building an extension to the current functions is a more cost-effective and quicker method to push the product to customers for feedback. Rapid iteration is used to produce quick prototype and get feedback from users to make revision and refinement. In addition, for this research, getting requirements for the business intelligence system and dashboard from customers have following limitations:

- Users are not knowledgeable about business intelligence system, dashboard, and restaurant performance measures
- Users do not know what data are being collected by the POS
- Users do not know if collected data are sufficient to calculate what they want to see
- Some user requests require development of new functions or changes to the infrastructure, hence impractical to achieve in the short-to-medium term

As a result, the approach for designing the business intelligence system is based on 2 elements:

1. Customer requirements on a performance dashboard from routine feedback collection
2. Feasibility based on the current POS functionalities and availability of data

Unfulfilled requirements that need further development can be kept for new feature development and later version of the dashboard.

The case-study company consistently gathers feedback from current customers via site visits and call centre. From feedback collected on dashboard improvement, the objective of the dashboard is to:

- show the current status of the restaurant and how it has been doing for the day
- show anomalies and frauds and errors
- show relative performance for comparison
- show non-financial performance measures

The target user is selected to be managers or restaurant owners because of the following reasons:

- Have the restaurant's best interest to increase profit and improve operations
- Possess higher cognitive level, capable of analytical thinking
- Able to make rational decisions
- Have the authority to makes changes to the restaurant

The frequency of use is expected to be 1-3 times per day. This implies that the information displayed must be updated frequently, near real-time in order to reflect the current status and performance. Historical data must also be displayed to show relative performance.

Only necessary and meaningful performance measures would be selected and displayed on 1 page of tablet-size screen. With these requirements in mind, the following sections dive into the steps to produce the 3 outputs namely, KPIs, dashboard design, and data warehouse.

3.2 KPI Selection

As presented in literature review section 2.1.2, Balance Scorecard (BSC) has been widely used by other researchers as a reliable framework to select KPIs for performance dashboard. For the case of restaurant dashboard, it was used by Liu and Chen (2013), and Abdillah and Diana (2018). Thus, BSC would be used as a guideline to select KPIs for dashboard display in full-service restaurants. However, the learning and growth perspective which consists of measures such as attendance rate, training, and turnover is excluded from KPI selection. This is because the POS does not have employee-related functions and thus do not collect data on human resource development. Thus, only financial, customer, and internal business process perspectives are considered in the KPI selection.

Firstly, the identified KPIs in section 2.1.1 are categorised into the 3 BSC perspectives. Then, elimination based on the functional capability and availability of data of the case-study POS is applied. System limitations include the lack of reservation and queue system, no record system for food and beverage costs, and no customer feedback system. There are also some data that are not collected by the POS such as who takes orders, who serves which table, number of times an item is unavailable, time taken to cook, and time taken for a waitress to take order or serve or check bills. Hence, there are certain metrics that cannot be calculated, thus eliminated from consideration. The elimination is shown in Table 3 below.

BSC Perspectives	Status
Financial	
Sales number	
Revenue per table	
RevPASH	
RevPAM	Eliminated

Average check size	
% Food loss	Eliminated
% Food costs	
% Beverage loss	Eliminated
Customer	
Top selling items	
Number of complaints	Eliminated
% Customers satisfied with the time to be served	Eliminated
% Tips from total collected	
% Cancelled reservation	Eliminated
% Positive feedback from guests	Eliminated
% Reserved table	Eliminated
Internal Business Process	
Number of customers	
Average meal duration	
# Guests per table	
Table turnover	
Table occupancy	
# Tables served per waiter	Eliminated
% Front of house labour	Eliminated
% Unavailability of menu items	Eliminated

Table 3 Categorisation of Performance Measures into BSC and 1st Elimination

After the first round of elimination, the list is still too extensive to be put into 1 tablet-sized page. A set of criteria for further elimination are based on the following:

- Whether the metric is useful to know in real-time

- Whether the metric can be easily understood by laymen
- Whether the metric is applicable in Thailand context
- Whether the metric is used to calculate another more useful metric, in which case only one metric is chosen

The reasons and result of the second round of elimination is shown in Table 4 below.

BSC Perspectives	Status
Financial	
Sales number	Selected
Revenue per table	Selected
RevPASH	Eliminated Difficult to understand No need to know in real time
Average check size	Selected
% Food costs	Eliminated No need to know in real time
Customer	
Top selling items	Selected
% Tips from total collected	Eliminated Not applicable in Thailand
Internal Business Process	
Number of customers	Eliminated Become a part of average check size
Average meal duration	Selected
# Guests per table	Eliminated Become a part of average check size
Table turnover	Selected

Table occupancy	Selected

Table 4 Summary of BSC after 2nd Elimination

Apart from showing restaurant performance, another objective of the dashboard is to highlight the anomalies that happen in the restaurant. Hence, one more metric, number of cancelled bills is added to the KPIs in order to help owners and managers monitor suspicious or erroneous events that might cost financial loss to the restaurant. At last, the final list of metrics in Table 5 below is chosen to become the Key Performance Indicators (KPIs) which will be shown on the dashboard. The processes and rationales for illustration and enrichment of each KPI are explained in section 3.3 below.

Financial	Internal Business Process
Sales number	Average meal duration
Revenue per table	Table turnover
Average check size	Table occupancy
Customer	Alerts & Anomalies
Top selling items	Cancelled bills

Table 5 Final List of KPIs

3.3 Design of Dashboard Display

The design of dashboard display is the third stage in the 5-step process of dashboard design proposed by Vilarinho, Lopes and Sousa (2017) in section 2.3.1. A mock-up is delivered at this stage. As a general guidelines suggested by Few (2006) in section 2.3.2, the research follows the use of standard set of colours for displaying graphs and charts and different saturation levels of the same hue to distinguish groups of data in charts. Other elements of visual perception proposed by Ware (2004) and Few (2006) such as length, spatial grouping, enclosure, and etc. will also be applied.

The research follows the three steps according to Zelazny (2001) explained in section 2.3.1 to transform data to chart. For each KPI, the first step is to identify the intended message it would like to inform users. Then, based on the message, data relationship and comparison type is chosen to best represent the meaning. Lastly, an appropriate display medium is selected for each KPI. The following sections explain the details of the three steps for each KPI.

3.3.1 Sales Number

The message that sales number would like to convey is whether a restaurant is doing better or worse financially for the day. Merely showing the number is not as useful as providing context for comparison. Only then can owners make an objective judgement on relative performance. Thus, historical benchmarks are needed to give context for meaningful comparison. In this case, two historical benchmarks are chosen:

- Sales of the same day last week: to compare with the most recent performance
- Average sales of the same day for the last 4 weeks: to see a month's performance improvement and also to average out abnormal performance in certain weeks, if any

The rationale for choosing the above two datasets is that restaurant sales are often dependent on time of day or day of week or week of month. It can be said that restaurant sales often have a regular pattern based on time. For example, a restaurant near office areas would sell better during weekdays' lunchtime than weekends. Thus, in order to judge if a Saturday's sale is good or not, it is not fair to compare it to a Friday or yesterday. A fair match would be to compare it to previous Saturdays. This is to give a context to managers or owners to see how well today is doing compared to the same day in prior periods. Thus, nominal comparison is chosen and a horizontal bar chart is a

suitable medium to display such as message. Figure 24 below shows a horizontal bar chart with the same green colour of different saturation levels. Here, the length of the bar chart can be processed pre-attentively to see relative performance. Exact sales amounts are also shown at the end of the bar.

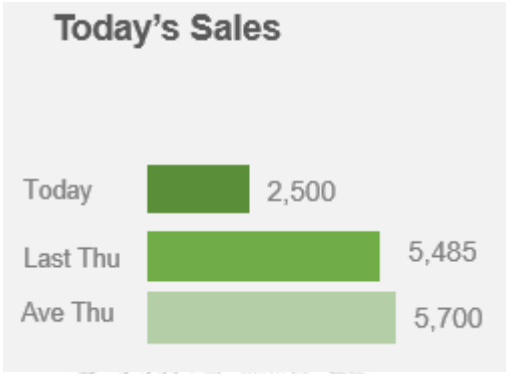


Figure 24 Bar Chart: Today's Sales VS Historical Benchmarks

Another useful comparison for sales number is a time-series and line chart is the most suitable medium for it. Figure 25 below shows today's sale number on a line chart, enriched by another line showing the trend of sales from the same day of last week for comparison. By looking at a line chart, it reveals 2 implications:

- How today's hourly sales are doing compared with those of the same day of last week
- The trend for the rest of the day based on last week's trend

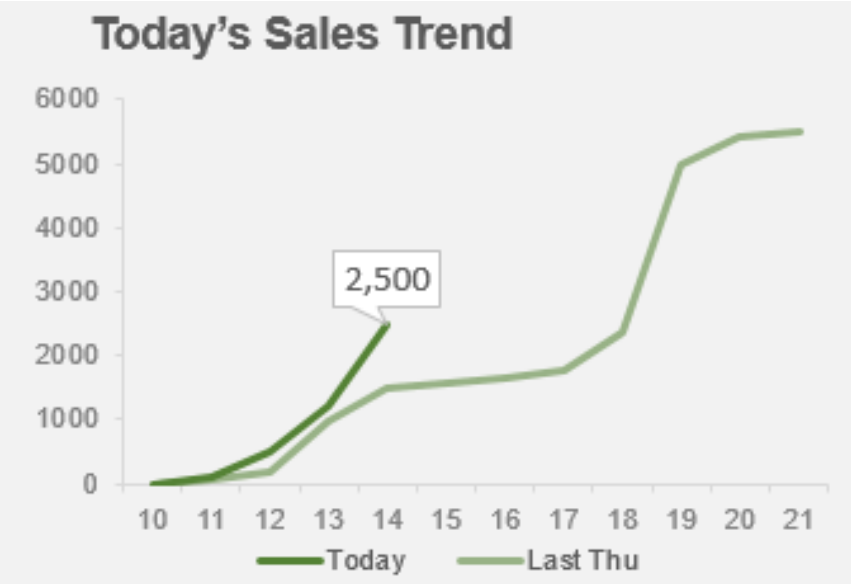


Figure 25 Line Chart: Today's Sales VS Same Day Last Week's Sales

It is common for restaurants to have weekly review, thus giving an overview of how current week is doing would help to take corrective actions quickly if performance is not good. Nominal comparison with last week's sales numbers are chosen to enrich the context. Figure 26 below shows a horizontal bar chart depicting total sales of each day for a week. This is to give users an evaluation of current week's performance against last week's. Bar chart is chosen to show length and the exact amount clearly. A different colour is used here to distinguish this segment from Today's sales. Other visual elements such as saturation level and exact amounts follow the same principles as above.

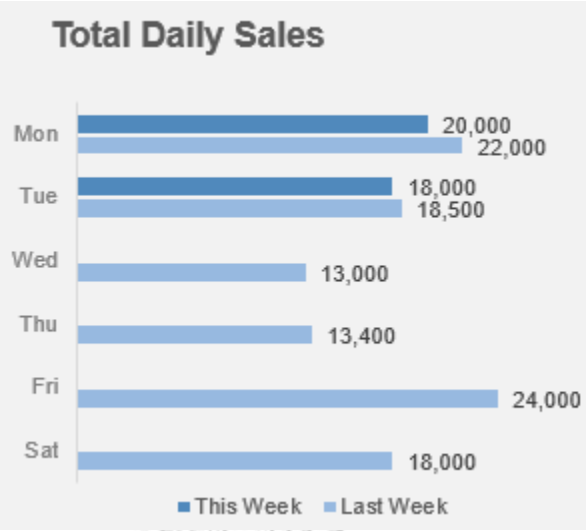


Figure 26 Bar Chart: Daily Sales in a Week

Taking a step further, Figure 27 below shows weekly sales number of current month compared with those of last month. Line chart is chosen to see a trend.

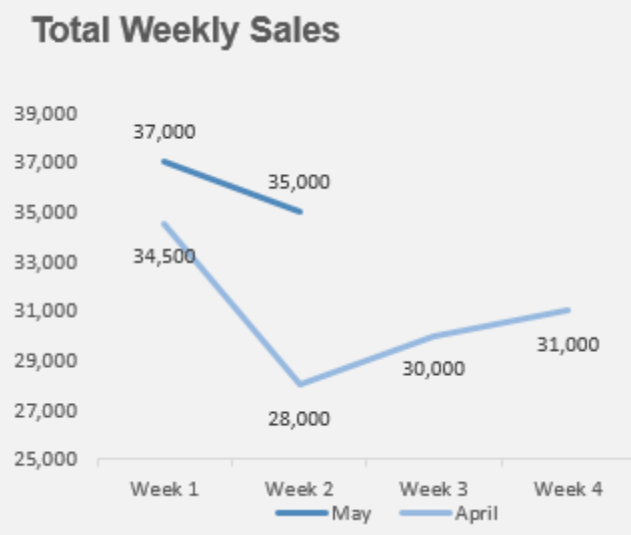


Figure 27 Line Chart: Weekly Sales in a Month

As seen above, sales number can be shown from hourly to weekly aggregates. Restaurant owners and managers are given several contexts to make judgement regarding financial performance. Actions after seeing this information could prompt

online posts or staff encouraging passerby to dine in order to boost today's sales. Other marketing activities such as promotions and happy hours can also be done to improve overall financial performance.

3.3.2 Average Meal Duration & Revenue per Table & Average Check Size Per Customer

For each occupied table, meal duration, revenue per table and check size per customer can be displayed in real time to show the current status of the restaurant. The intended message for showing these metrics is to reveal for each occupied table, whether:

- Customers have been sitting for too long
- Customers are generating a reasonable amount of revenue, given the number of customers at that table

In order to evaluate the above, benchmarks need to be established for nominal comparison. Restaurants of different sizes and food types would have different values for the 3 metrics, thus the benchmarks are calculated from own restaurant's historical data. The following benchmarks are defined:

- Average meal duration is calculated by taking the sum of meal duration in last week and dividing it by number of meals.
- Average revenue per table is calculated by taking the sum of all paid bill values in last week divided by the number of bills.
- Average check size per customer is calculated by dividing the sum of all paid bill values with total number of customers in last week.

In order to allow for easy comparison, a table grouping these three metrics and showing exact amounts is chosen as an appropriate medium to display changing data in real time. In Figure 28 below, the three average benchmarks are shown on the top row while the remaining rows displays real-time information for comparison. Numbers are aligned right so that it is easier to see the number of digits (longer number of digits means higher value). Aligning centre makes it harder to compare numbers vertically. Due to limited space on a dashboard, only the top five longest occupied tables are shown. Apart from nominal comparison, deviation can be highlighted in red to show when the duration or the revenue (bill amount as shown in Figure 28) or check size per customer is more than the benchmark, alerting managers to look into possible reasons and take actions to improve the situation and performance.

Meal Duration & Bill Amount & Check Size Per Customer

	Meal Duration	Bill Amount (Baht)	Check Size per Customer(Baht)
Benchmark	1:01	501	231
Table 1	1:59:01	1,670	334
Table 4	1:30:01	250	250
Table 11	1:05:57	1,344	672
Table 20	48:48	480	240
Table 8	42:02	300	100

Figure 28 Amount of Dining & Average Check Size Per Customer

These three metrics have implications on operations improvements. For example, if meal duration is abnormally long for a table, managers could investigate further and make corrective actions. Possible reasons for long occupancy could be due to

- Customers really sitting too long chatting or doing work
- Operational issues such as dishes taking a long time to cook and serve, forgotten orders, missed orders

Another scenario could be when check size per customer is low. For example, in a restaurant with an average dining amount of 400 THB (10 GBP) and average check size per customer of 160 THB (4 GBP), a table has been occupied for an hour with dining amount of 200 THB (5 GBP) and check size per customer of 40 THB (1 GBP). This implies that this table is not contributing as much as it could and thus, there is a potential to drive more sales from this table. If the restaurant is still empty, actions can be taken to get more sales from customers by offering upselling and cross-selling. On the other hand, if the restaurant is packed, managers might consider asking them to leave politely as it might have a chance to earn more money if new customers come in to replace the existing group.

3.3.3 Top Selling Items

Top selling items shows what menu items are selling well for the day. Ranking is the data relationship and Few (2012) advocated the use of bar chart, instead of pie chart to display ranking. Thus, bar chart is chosen to represent this information. Top selling items are closely linked to inventory and thus, inventory level, although not part of selected KPIs, is added provide contextual information to paint a more complete picture. Decisions can be made if the two are presented together. On the other hand, items not sold well are also presented to show the other end of the spectrum as shown in Figure 29 below. Red text highlights extremely low inventory level to alert users to take a closure look.

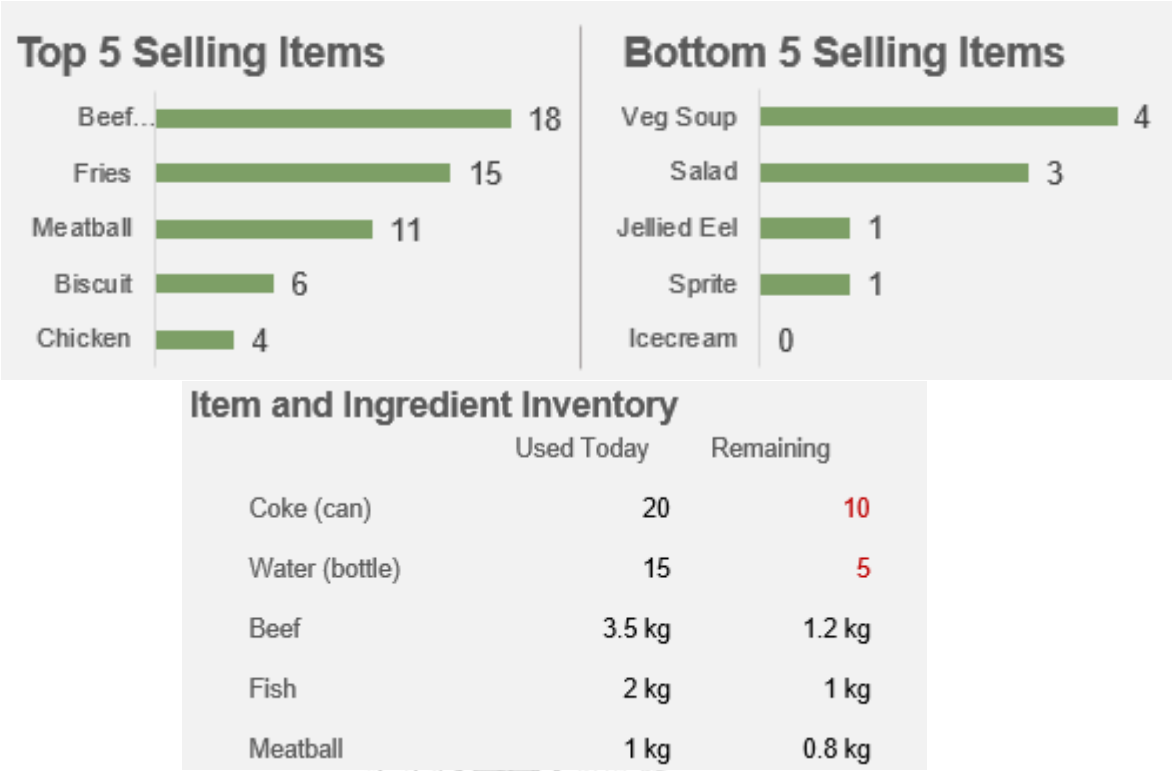


Figure 29 Top and Worst Selling Items, and Inventory Level

3.3.4 Table Occupancy and Table Turnover

The intended message for showing these metrics is to show table utilisation in real time. Table occupancy is often represented by percentage e.g. 60% table occupancy rate. However, percentage is hard to interpret thus this part-to-whole relationship is presented by fraction instead. The fraction shows the number of occupied tables over total number of tables as shown in Figure 30 below. Here it is clear to users that 18 tables out of 20 are occupied as no calculation is need to convert to absolute numbers. Table turnover is shown as a simple number which changes hourly.

Figure 30 Table Occupancy and Table Turnover

3.3.5 Anomaly Detection and Alerts

Anomalies and alerts are essential parts of dashboard as it alerts users to investigate and take actions to correct abnormal or emergency cases. Number of cancelled bills is shown as an absolute number and would be highlighted in red if it is higher than an arbitrary threshold to grab attention from users as shown in Figure 31 below. A high number of cancelled bills is concerning due to potential fraudulent activities or incompetency of staff or poor customer service or items running out of sales. These require immediate attention from managers and owners to investigate and fix.

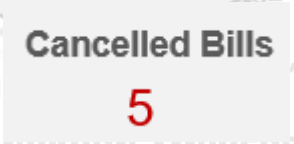


Figure 31 Alerts and Anomalies: Cancelled Bills

At this stage, all selected KPIs have been provided context to express intended messages and identified appropriate visual media to communicate effectively to users. The last step is to put all KPIs into 1-page tablet-sized display.

3.3.6 Dashboard Mock-up

The arrangement of KPIs follow the above groupings from section 3.3.1 to 3.3.5. According to Few (2006), enclosure is one of the attributes in visual perception that is effective in grouping sections of information together. In the dashboard mock-up shown in Figure 32 below, enclosure is in the form of a grey colour filled behind the content.

The first spot humans are drawn to when reading is the top left, followed by centre and top right, and bottom right is usually the last spot. Hence, the arrangement of the KPIs is based on information update frequency. Referring to Figure 32 below, real-time information such as table occupancy, meal duration and related metrics are put at the top of the page. Anomaly reporting of cancelled bills is also put on top to draw attention to potentially emergency events. More static information such as daily and weekly sales, and top-selling items are put the bottom of the page. Thus, the more frequent or critical it is, the higher the priority for it to be put on the more prominent spots.

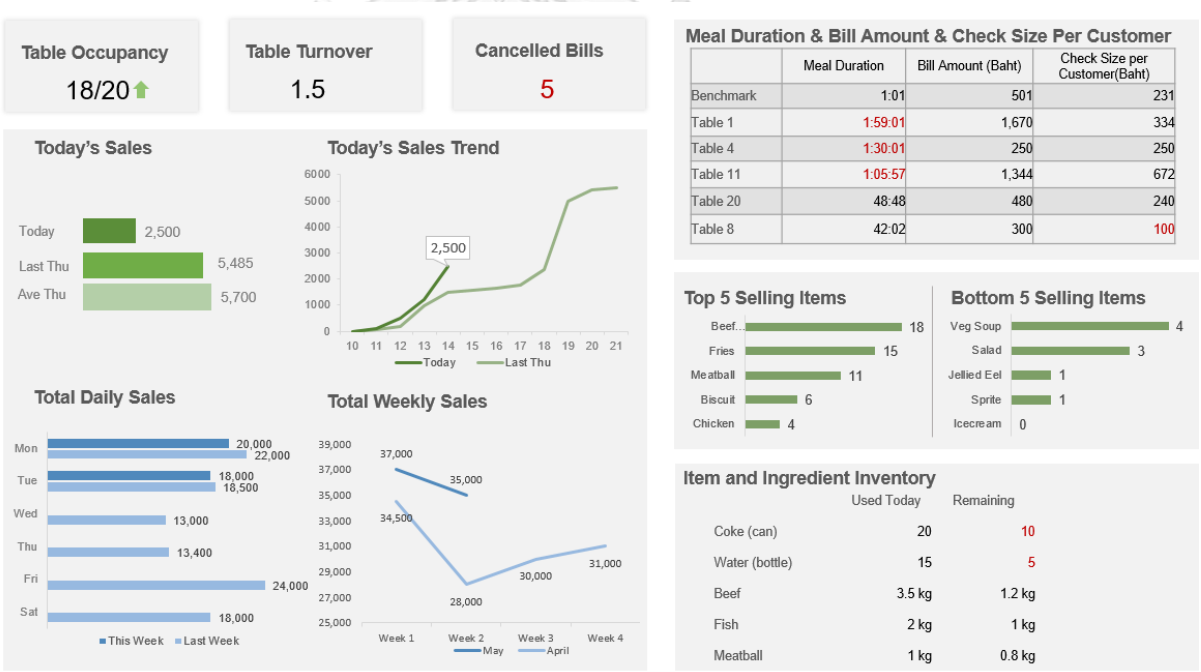


Figure 32 Dashboard Mock-up

Table 6 summarises the selected data relationships and context for each KPI. It also includes the implication and possible use cases of the KPIs.

KPI	Data Relationship	Context	Implication
Sales number	Nominal, Time-series	Same day of last week, Same day in the last 4 weeks	Make an objective and informed judgement on performance relative to previous performance Forecast how sales trend might be for the rest of the day based on historical trend
Check size per customer	Nominal	Average check size per customer of last week	Give signal to staff to manage tables better. For example, if sales generated from table is not proportional to the number of customers i.e. average sales/customer is low, staff could intervene by recommending them to order more. In the event that the restaurant is packed, staff might want to politely and indirectly signal them to check bill.
Top 5 dishes & ingredient level	Ranking	Best 5 and Worst 5	Best-selling dishes use up the most ingredients, hence it is likely that the constituent ingredient might be low in supply. Looking at these two aspects together, it can prompt intervention from waiters. For example, if certain ingredients are not using up fast enough, managers can order waiters to recommend particular dishes to customers to order.

Table occupancy	Nominal	Meal duration	This indicates table utilisation and shows the meal duration of the current longest-seating tables and compares them with last week's average. Together, they could help improve table management and also highlight anomalies.
Cancelled orders	-	-	This helps to quickly detect abnormal activities which could be caused by potential frauds or hiccups in operations that require immediate attention and resolution. Early detection can alleviate losses and negative impacts.

Table 6 Summary of KPIs and Their Implications

In summary, the KPIs shown on the dashboard would help owners and managers in the following areas:

- Get overview of the current status in multiple aspects including sales, operations, inventory, resource utilisation and anomaly
- Make objective judgment on performance based on comparison with historical data
- Monitor progress as a result of changes and correction
- Early detection of potential problems in the area of operations e.g. long table duration could mean slow cook or customers sitting too long. A lot of cancelled items could be a result of depleted inventory or staff mistakes. Such red flags prompt quick investigation and response to improve the situation
- Minimise fraudulent activities as all data are transparent and must be reconcilable

- Losses due to frauds and mistakes could be minimised as anomaly reporting can surface problems early thus there is no need to wait till end of day to reconcile numbers
- Users make more informed and well-rounded decision as problems are supplemented with multi-dimensional information

From the above set of KPIs and mock-up, the next step is to design how the data structure of the data warehouse would look like in order to deliver these KPIs. Section 3.4 elaborates the processes to create the design of data warehouse.

3.4 Design of Data Warehouse

The current database is an operational database using Online Transaction Processing (OLTP). It is the main production database for the whole POS system. It is used to manage and store every transaction data from restaurants in real time. New transactions and changes are coming in constantly to record what items were sold, at what time, at what price, by which restaurant. It is not advisable for the BI system to retrieve data from this operational database as it would disrupt the working of the operational database and negatively slow down the performance of the whole POS system.

Moreover, data in the operational database are in a raw and detailed format which is not inappropriate for reporting and analysis purposes in BI system. BI system requires a different type of database structure which stores aggregate values over time, providing historical records in multiple dimensions and handle complex queries more efficiently. Thus, this requires a new design of a data warehouse and dimensional modelling as discussed in section 2.4 above will be used to design the data structure of the new data warehouse.

Based on the KPIs and contextual information identified in section 3.3, the following data are needed to be taken from the data warehouse:

- Historical hourly, daily, and weekly sales numbers
- Last week's average meal duration
- Last week's average dining amount
- Last week's average check size
- Historical number of customers

The steps to design data warehouse follows the 4 steps to dimensional design process by Kimball and Ross (2013) as discussed in section 2.4.

3.4.1 Select the Business Process

In restaurant setting, there are many processes from start to end. However, not all of the actions are captured by the case-study POS. The processes are listed below and the events that can be captured by the POS are indicated with 'captured' in parentheses.

1. A customer arrives at the restaurant
2. A customer sits at a table
3. A waitress brings a menu
4. A waitress takes an order (captured)
    a. Item
    b. Quantity
    c. Ordered time
    d. Table
    e. Number of customers
5. An order is sent to the kitchen

6. Dishes are delivered
7. Check is requested
8. Payment is made (captured)
    a. Dining amount
    b. Discount
    c. Paid Amount
    d. Method of payment
    e. Paid time

Hence, the process at which every piece of data is concluded is step 8 where sales number, meal duration, and number of customers are finalised and recorded. Thus, sales transaction is selected as the business process.

3.4.2 Declare the Grain

The level of grain needs to be at transactional level in order to allow the calculation of the selected KPIs. Each transaction is recorded as 1 row. Hourly, daily, and weekly numbers can be aggregated by summing transaction data.

3.4.3 Identify the Dimensions

The act of paying for a meal consists of knowing where (table), when (time), payment method, and how much as a basic information. These aspects of information form dimension tables. Sections below explain the details of attributes and relationships in term of primary and foreign key of each dimension. PK is a primary key which is a

unique identifier of a particular row of data and usually used as foreign key to connect with other tables.

Time Dimension

Time dimension contains a surrogate key as the primary key. Attributes explain the characteristics of a time. Table 7 shows the attributes and their descriptions.

Hierarchy: min -> hour -> period -> day/night

Time		Description
PK	time_key	primary key, surrogate key
	hour_number	the hour e.g. 8,9,13,23, etc.
	min_number	the minute e.g. 1, 59, etc.
	period_name	morning, afternoon, evening, etc.
	day_night	day time or night time
	close	whether the shop is close at this hour

Table 7 Time Dimension

Date Dimension

Separation of Date and Time dimensions are easier to manage and to query. It is easier to analyse cyclical and recurring daily events if Date and Time are separate dimensions, which is required by the selected KPIs and dashboard design. Table 8 shows the attributes and their descriptions.

Hierarchy: date -> week -> month -> year

Date		Description
PK	date_key	primary key, surrogate key
	day_name	e.g. Sunday, Monday

	date_number	e.g. 1,3,15, 31
	month_number	ranging from 1 - 12
	month_name	e.g January, December
	year_number	e.g. 2018, 2008
	week_number	ranging from 1 - 52
	calendar_quarter	e.g. 1st, 2nd, 3rd, 4th
	weekend	whether it is a weekend
	public_holiday	whether it is a public holiday
	store_close	whether store is close

Table 8 Date Dimension

Table Dimension

Table dimension collects information about each table such as which store a table belongs to, the location, and how many seats it holds. Table 9 shows the attributes and their descriptions.

Hierarchy: town -> district -> province

Table			Description
PK	table_key		primary key, surrogate key
	table_number		table number in store
	number_of_seats		number of seats for that table
	store_ID		store at which the table is
	store_name		name of store
	location_province		name of province e.g.

			Bangkok
	location_district		name of district e.g. Dusit
	location_town		name of town e.g. Makkasan

Table 9 Table Dimension

Payment Method Dimension

Payment method dimension specifies which payment method was used for each transaction. Each method might have different commission rate which has implication on profits. For example, credit cards have around 1% commission on the bill value. Table 10 shows the attributes and their descriptions.

Payment_method			Description
PK	payment_key		primary key, surrogate key
	method		method of payment e.g. cash, credit
	commission		commission rate e.g. 1% credit card

Table 10 Payment Dimension

3.4.4 Identify the Facts

Sales fact table stores measures of each successful transaction. The measures are dining amount (sales), duration, and number of customers. Facts in this table are additive facts because they can be summed up through all dimensions. Table 11 shows measures, dimension keys, and their descriptions.

Sales		Description
PK	sales_key	Primary key, Surrogate key
FK	time_key	To identify the time this sale occurred
FK	date_key	To identify the date that this sale occurred
FK	table_key	To identify the table that this sale occurred
FK	payment_key	To identify payment method
	dining_amount	Total sales amount paid for this sale
	duration	Meal duration in minutes
	customer	Number of customers

Table 11 Sales Fact

3.4.5 Data Warehouse Schema

Star schema is the most suitable because there is only 1 fact table that connects to dimensions. Figure 33 below show the final schema. Each dimension is connected to sales fact table via respective foreigner keys.

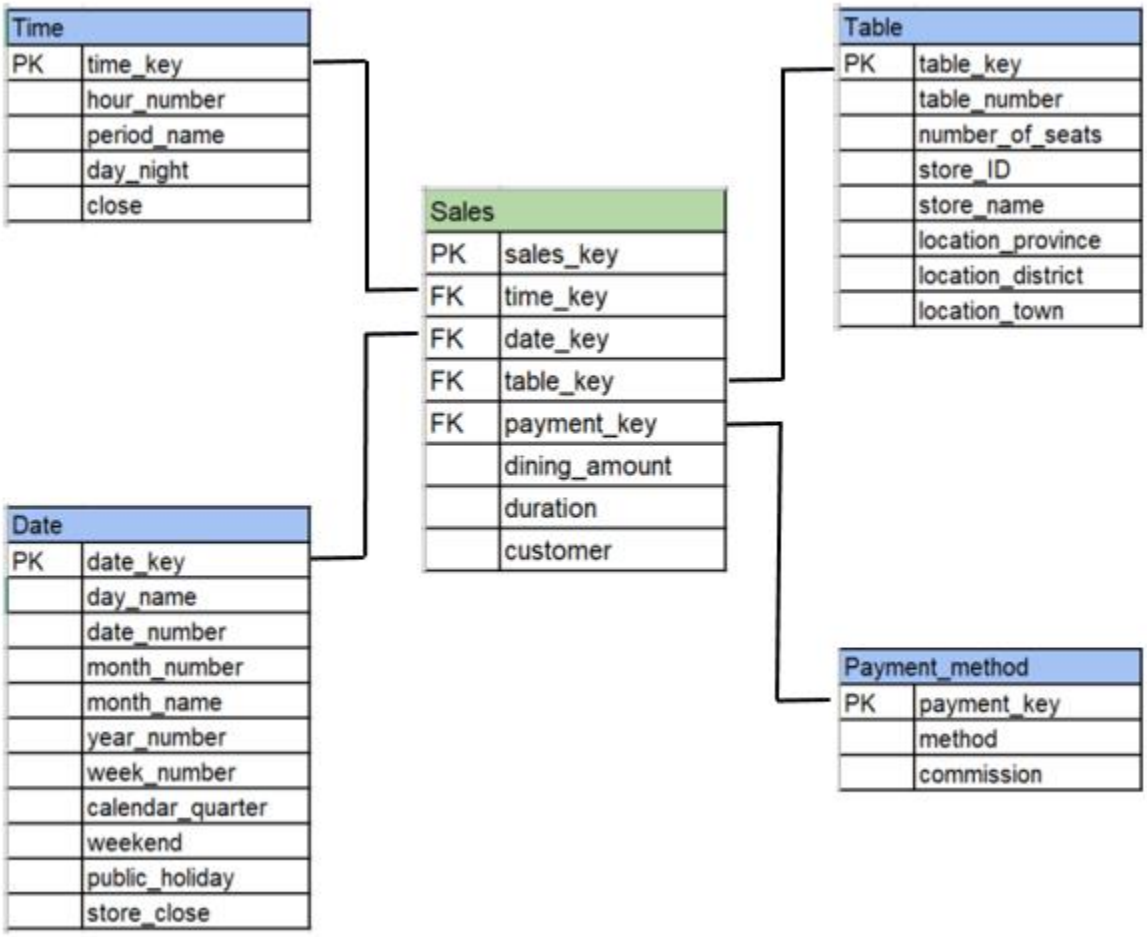


Figure 33 Final Star Schema for the Restaurant BI System

3.4.6 Design of Physical Data Model

The last step needed before implementation is to finalise the physical data model where table names, column names, and data types are defined.

Time Dimension

Table 12 shows the attributes and their data types. Numeric values use INTEGER while texts use VARCHAR data types.

Time	
PK	time_key: INTEGER
	hour_number: INTEGER
	period_name: VARCHAR(20)
	day_night: VARCHAR(20)
	close: BOOLEAN

Table 12 Physical Data Model of Time Dimension

Date Dimension

Table 13 shows the attributes and their data types. BOOLEAN is used to indicate binary option: yes or no.

Date	
PK	date_key: INTEGER
	day_name: VARCHAR(20)
	date_number: INTEGER
	month_number: INTEGER
	month_name:VARCHAR(20)
	year_number: INTEGER
	week_number: INTEGER
	calendar_quarter: INTEGER
	weekend: BOOLEAN
	public_holiday: BOOLEAN
	store_close: BOOLEAN

Table 13 Physical Data Model of Date Dimension

Table Dimension

Table 14 shows the attributes and their data types.

Table	
PK	table_key: INTEGER
	table_number: INTEGER
	number_of_seats: INTEGER
	store_ID: INTEGER
	store_name: VARCHAR(50)
	location_province: VARCHAR(50)
	location_district: VARCHAR(50)
	location_town: VARCHAR(50)

Table 14 Physical Data Model of Table Dimension

Payment Method Dimension

Table 15 shows the attributes and their data types. Decimal uses FLOAT data type.

Payment_method	
PK	payment_key: INTEGER
	method: VARCHAR(50)
	commission: FLOAT

Table 15 Physical Data Model of Payment Method Dimension

Sales Fact

Table 16 shows the measures, dimension keys, and their data types.

Sales	
PK	sales_key: INTEGER
FK	time_key: INTEGER
FK	date_key: INTEGER
FK	table_key: INTEGER
FK	payment_key: INTEGER

	dining_amount: FLOAT
	duration: INTEGER
	customer: INTEGER

Table 16 Physical Data Model of Sales Fact

With this physical data model, the design of data warehouse is complete and ready to be implemented. However, actual implementation is out of the scope of this research. The next step is to evaluate the design of dashboard display to ensure that users are more satisfied with the new dashboard design and find it more useful than the current one.

3.5 Evaluation of New Design

Evaluation of the new design is done through a questionnaire. The objective is to validate that the new dashboard design has higher satisfaction score than the current one from current users of the POS.

3.5.1 Questionnaire

The questionnaire is broken down into 4 parts below:

1. Score rating of 1 to 10 in order to capture the magnitude of difference more accurately.
    a. Current design
    b. New design
2. 5-point Likert scale using descriptive terms to rate how much respondents agree with the statements.
3. Ranking of the top 3 and bottom 3 of KPIs in term of usefulness
4. Additional qualitative feedback and suggestions

The questionnaire was created and hosted online by Google Forms. The questionnaire form is shown in Appendix E in Thai. Information leaflet was given and consent was received prior to the start of the questionnaire. Both forms can be found in Appendix A, B, C, and D in both English and Thai versions.

3.5.2 Sample Selection

The sample for the survey was obtained from the company database. The criteria for choosing were as follow:

- Full-service restaurants
- Had used the software for more than 6 months
- Located in Bangkok (for ease of commute)
- Had experience using the current dashboard

The target respondents were restaurant owners or managers who could make decisions and changes on restaurant operations. Shops were contacted in advance to screen if they had used the current dashboard before. Only those that used before would be made an appointment with either owners or managers.

3.5.3 Interview Session

Consent form and Participant Information Leaflet were given to participants electronically to accept prior to doing the questionnaire and interview session. Both documents are shown in Appendix A, B, C, D in both English and Thai versions. After consent had been signed, interviews were conducted face-to-face with respondents.

URL of the questionnaires was given to respondents on the interview day. Researcher and respondents sat down together to go through the form and submit on the spot.

The questionnaires were carried out with 20 respondents and the results are evaluated and presented in the next chapter.

Chapter 4 Results and Discussion

4.1 Respondents

As shown in Figure 34, out of 20 respondents, 80% (16) are owners and 20% (4) are managers.

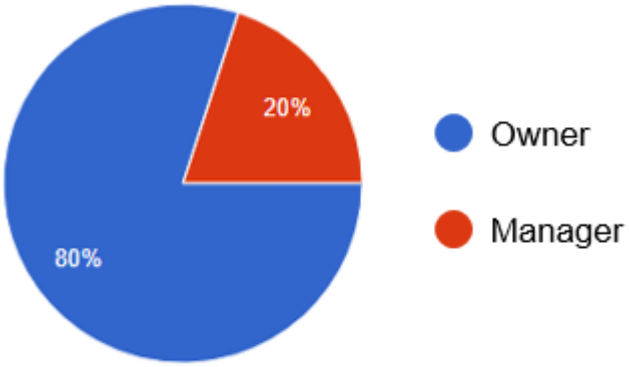


Figure 34 Respondents

4.2 Restaurant Size

As shown in Figure 35, out of 20 restaurants, 30% (6) are small, 50% (10) are medium, and 20% (4) are large.

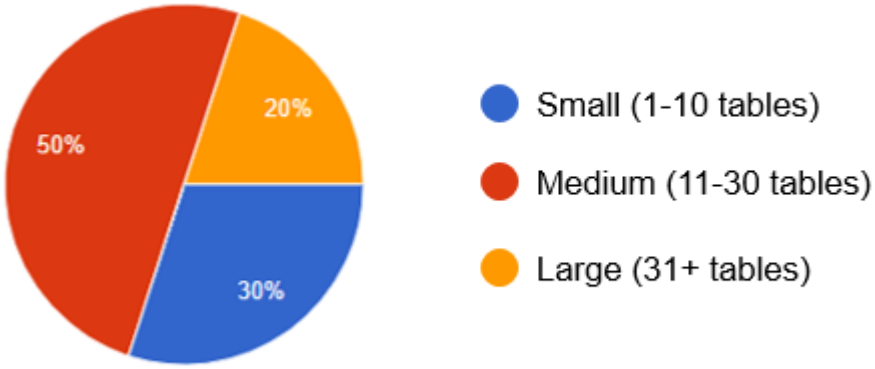


Figure 35 Restaurant Size

4.3 Scores of Current Dashboard

The mean score of the current dashboard is 6.7 while the median is 7.

Maximum is 8 while minimum is 5.

Figure 36 below shows the distribution of scores of the current dashboard rated by 20 respondents.

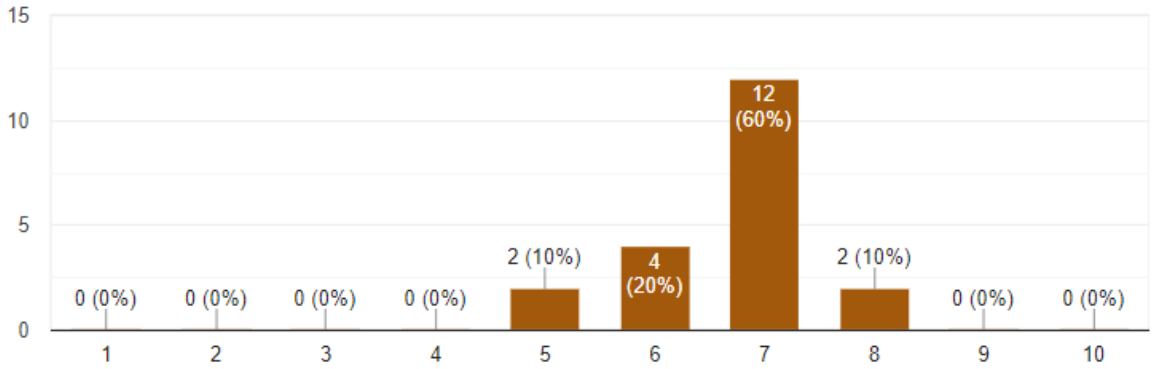


Figure 36 Scores of Current Dashboard

4.4 Scores of New Dashboard

The mean score of the current dashboard is 8.7 while the median is 9.

Maximum is 10 while minimum is 7.

Figure 37 below shows the distribution of scores of the new dashboard given by 20 respondents after showing them the new design.

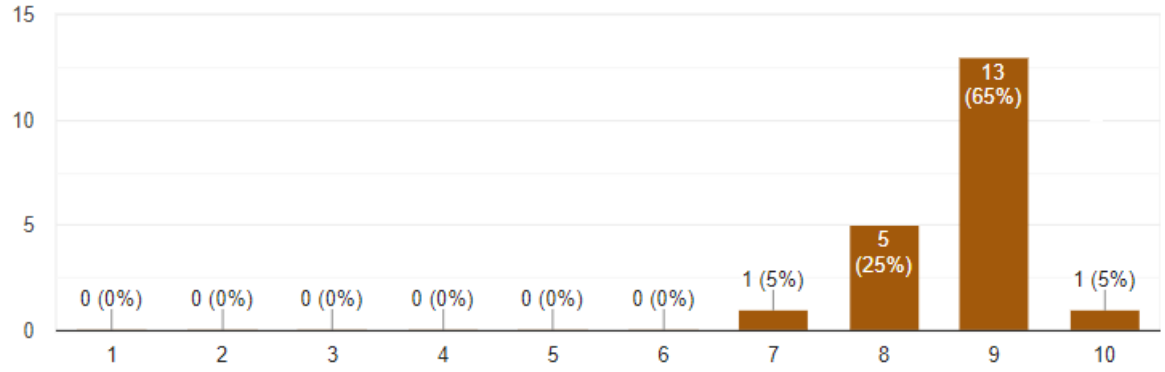


Figure 37 Scores of New Dashboard

4.5 Statistical Analysis – Wilconxon Signed Rank Test

A total of 20 respondents and the satisfaction scores of current dashboard and the new dashboard were collected. The data are shown in Table 17 below.

Respondent	Current Dashboard	New Dashboard
1	7	8
2	6	9
3	6	7
4	7	9
5	5	9
6	5	9
7	7	8
8	6	8
9	7	9
10	6	9

11	7	9
12	7	9
13	8	10
14	7	8
15	7	8
16	7	9
17	7	9
18	7	9
19	8	9
20	7	9

Table 17 Raw Data of Scores of 2 Dashboard Designs

Using Shapiro-Wilk Test to check for normality, the result shows that both datasets of scores do not follow a normal distribution. Thus, a nonparametric test, Wilcoxon signed rank test is used to test whether users are more satisfied with the new dashboard design than the current one.

Hypothesis

Let median of current dashboard's score be $\tilde{\mu}_1$ and median of new dashboard's score be $\tilde{\mu}_2$.

The hypothesis is stated below:

H_0: The median difference is zero or $\tilde{\mu}_1 = \tilde{\mu}_2$.

H_1: The median difference is positive or $\tilde{\mu}_1 < \tilde{\mu}_2$.

The test is a one-tail test with level of significance α=0.05.

The test statistics is W which is the smaller of W^+ (sum of the positive ranks) and W^- (sum of the negative ranks). The null hypothesis is rejected if the observed value of W is less than or equal to the critical value.

The difference between scores given by each respondent is calculated and then ranked ascendingly based on absolute values of the differences. Ranks are assigned from 1 through n to the smallest through the largest absolute values of the differences. Mean ranks are assigned when there are ties in the absolute values of the differences. The ranking is shown in Signed Rank column in Table 18 below.

Current Dashboard	New Dashboard	Difference	Signed Rank
7	8	1	+3.5
6	7	1	+3.5
7	8	1	+3.5
7	8	1	+3.5
7	8	1	+3.5
8	9	1	+3.5
7	9	2	+11.5
6	8	2	+11.5
7	9	2	+11.5
7	9	2	+11.5
7	9	2	+11.5
8	10	2	+11.5
7	9	2	+11.5
7	9	2	+11.5
7	9	2	+11.5
7	9	2	+11.5
6	9	3	+17.5
6	9	3	+17.5
5	9	4	+19.5

5	9	4	+19.5

Table 18 Difference and Signed Rank

W^+ = sum of all positive ranks = 210

W^- = sum of all negative ranks = 0

Test Statistic, W = smaller of W^+ and W^- = 0

Result

For one-tailed test with α=0.05, the critical value is 60 when N =20.

Obtained W = 0

Critical value = 60

The obtained value of 0 is less than 60, thus the null hypothesis, H_0 is rejected.

Thus, there is a statistically significant evidence at α =0.05 to show that users prefer the new dashboard design to the current one.

4.6 Questionnaire Results

The questionnaire also asked respondents to rate the effectiveness of the information on the dashboard on reflecting the current status of the restaurant, BSC perspectives, impact on decision making, and overall visual design. The Likert rating is a 5-scale rating from Strong Agree to Strongly Disagree. Users find that the dashboard is more useful in showing financial perspectives and the current situation than other perspectives. The detailed results are shown below.

4.6.1 Current Situation of the Restaurant

The results show that the new dashboard design shows the current situation well with all responses indicating either Strongly Agree or Agree as shown in Figure 38. This could

be due to the dashboard emphasis on showing real-time performance measures especially in the area of sales, table occupancy and table usage, and inventory level. Monitoring and alerting anomalies also provide users with a sense of control.

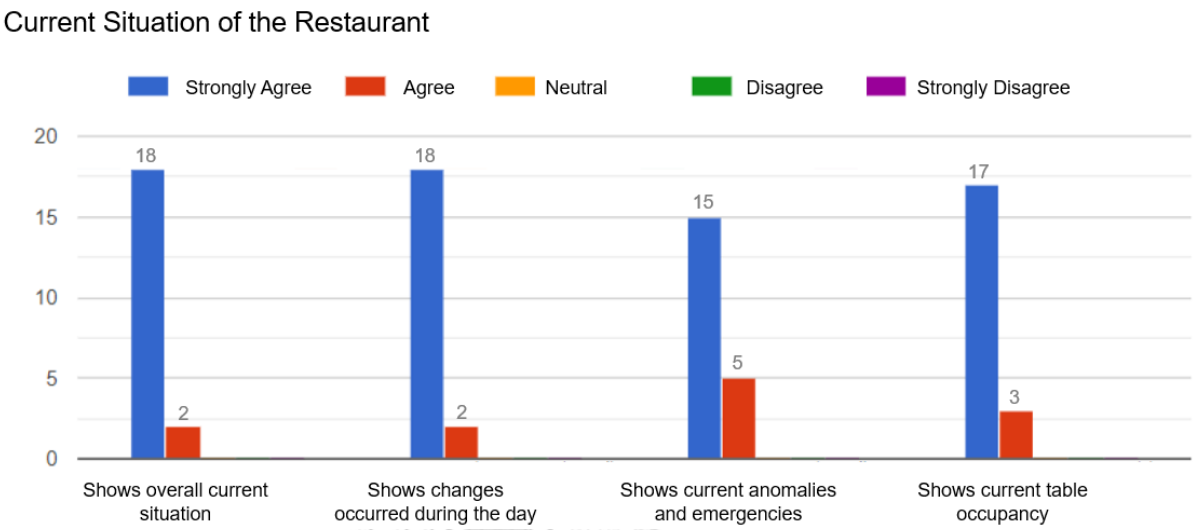


Figure 38 Responses on Current Situation of the Restaurant

4.6.2 BSC's Financial Perspective

The result shows overwhelmingly positive feedback on the new dashboard showing financial KPIs effectively and usefully. All users responded with either Strongly Agree or Agree as shown in Figure 39 below. Contextual information including last week's number and 4-week averages allow users to make meaningful comparison and critical analyses.

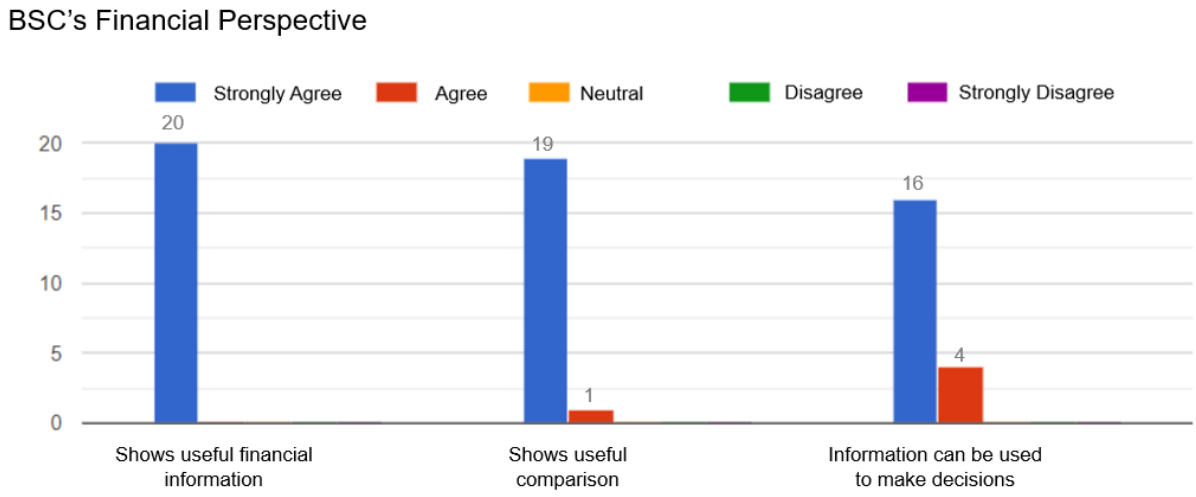


Figure 39 Responses on BSC's Financial Perspective

4.6.3 BSC's Customer Perspective

As shown in Figure 40 below, the responses show that the information is useful but might be lacking in term of helping decision making. This could be because there is not entirely practical for a restaurant to instantly increase number of customers or to rush out customers who have been sitting for a long time. Thus, information in this perspective might not be able to prompt immediate actions by owners or managers.

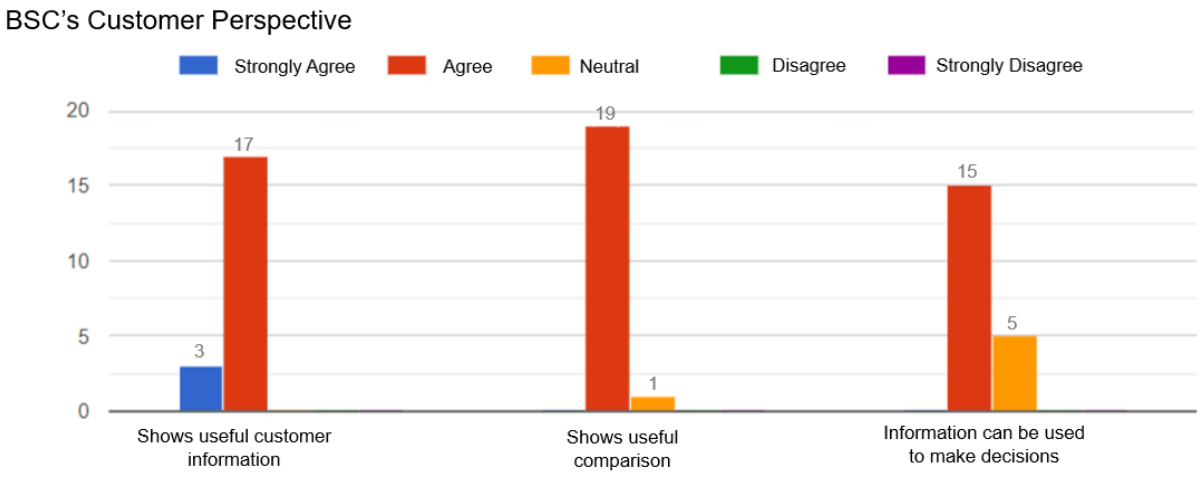


Figure 40 Responses on BSC's Customer Perspective

4.6.4 BSC's Internal Business Process Perspective

For this perspective, the general response is that knowing table occupancy and table turnover is not very actionable as shown in Figure 41 below. They are more of a monitoring measure than a deciding one.

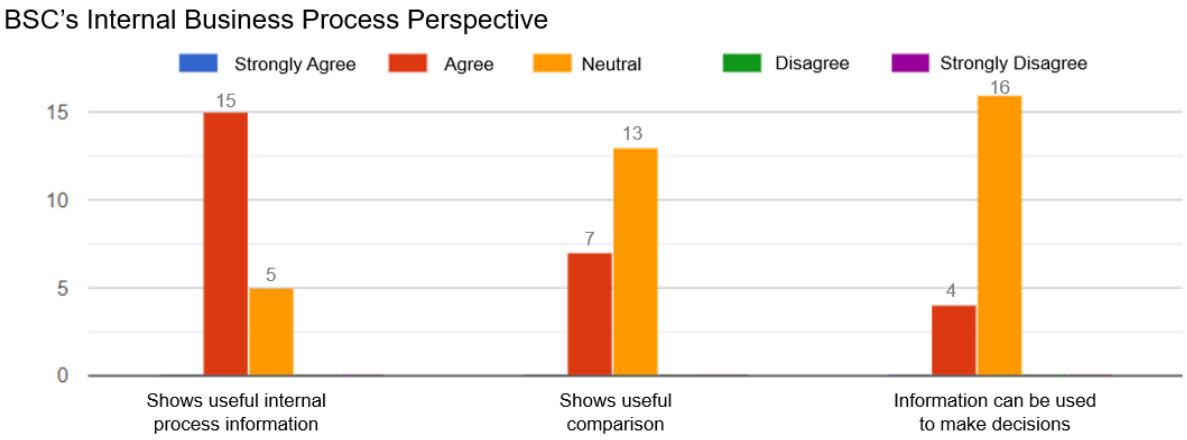


Figure 41 Responses on BSC's Internal Business Process Perspective

4.6.5 Visual Design

Overall, respondents are satisfied with the visual design as shown in Figure 42 below. The grouping of information makes sense to users. The good selection of display media makes information easy to digest by users. Aesthetics, colour, and font selection are subjected to preferences but overall deemed as appropriate.

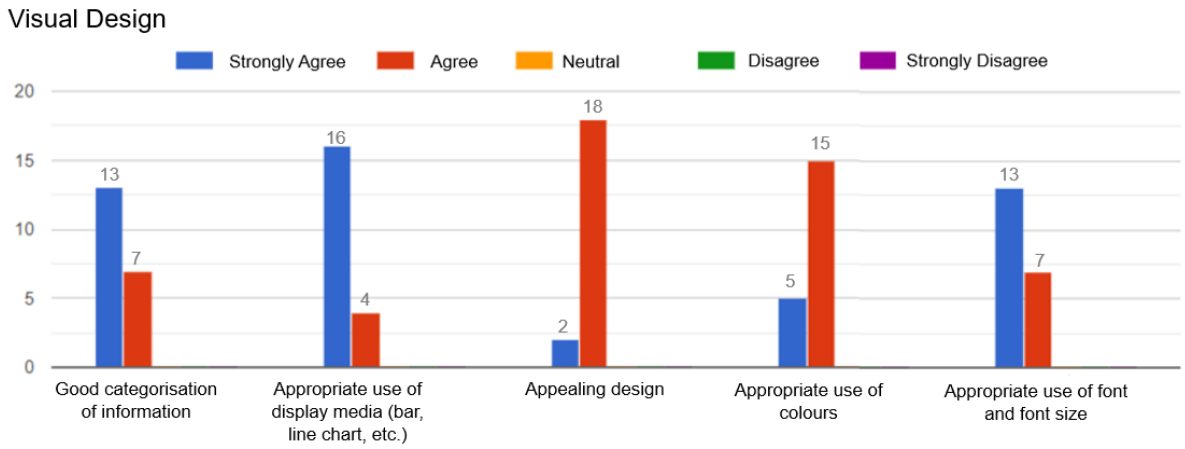


Figure 42 Responses on Visual Design

4.6.6 Impact on Decision Making

Respondents particularly found the financial perspective most useful and actionable but less so for customer and internal business perspective as shown in them having more Neutral responses in Figure 43 below. This could be due to certain limitations on what can be done in reality in term of customers and table usage. Inventory management and change monitoring gathered good responses.

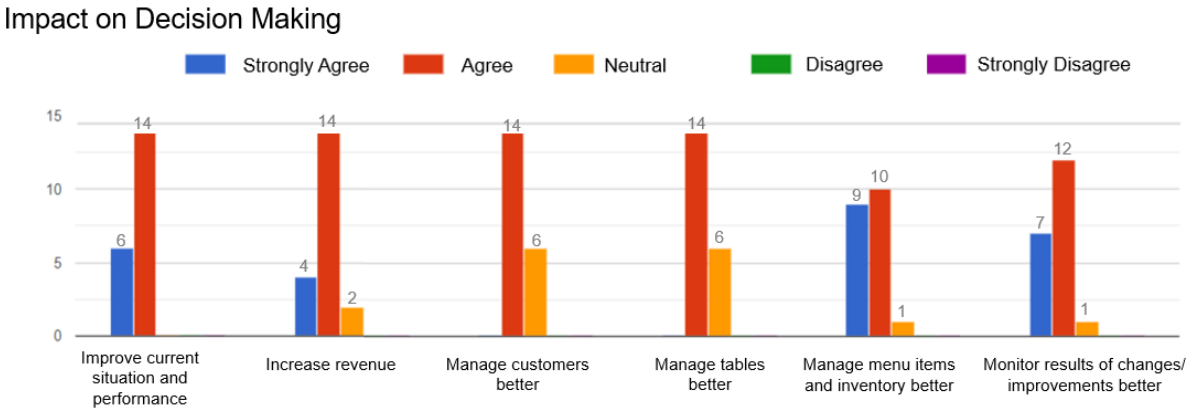


Figure 43 Responses on Impact on Decision Making

4.7 Ranking of KPIs

Respondents were asked to rank their top 3 and bottom 3 of the presented KPIs in term of usefulness. The most useful KPIs are:

1. Today's Sales
2. Inventory
3. Anomalies

The least useful KPIs are:

1. Table Turnover
2. Total Weekly Sales
3. Total Daily Sales

Table turnover was not understood by a lot of respondents and thus rendering it useless to users. Weekly and daily sales numbers are too detailed to know in a dashboard and they are all squeezed tightly in a small space that there is too much information to make sense. They would have been useful in a report that users can view weekly or monthly.

As a result of the ranking, the table turnover and the two sales charts are removed to make space for anomaly alerts. Other types of possible anomalies with significant negative impact such as cancelled items and refunded bills could be added instead.

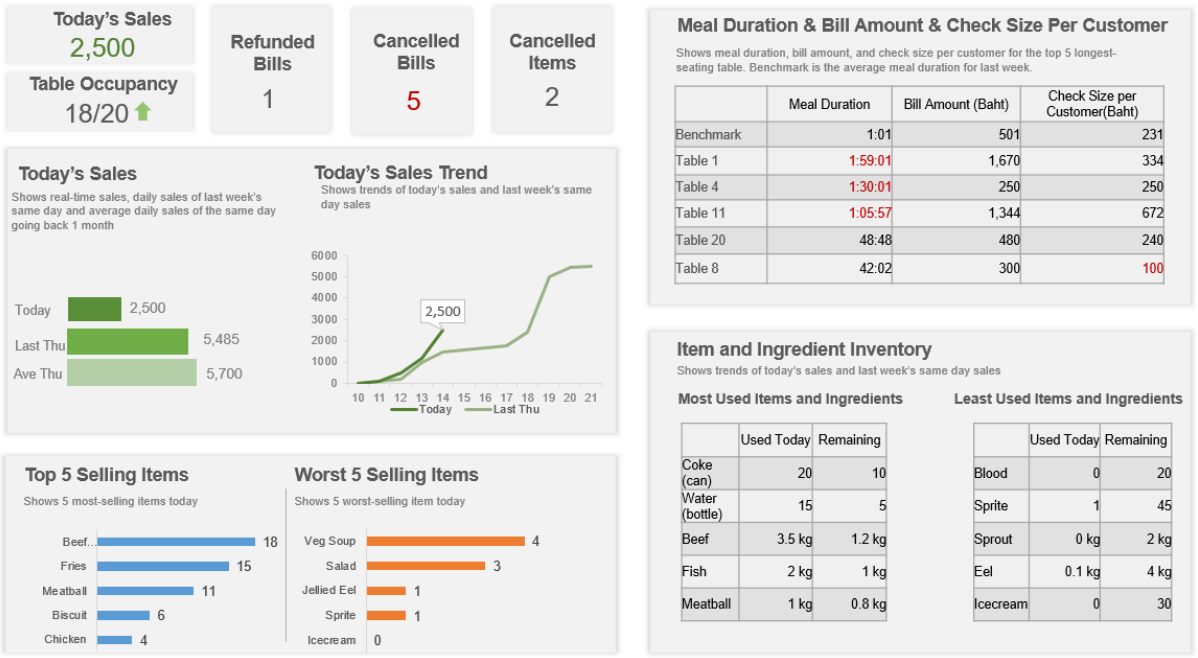
4.8 Other Qualitative Feedbacks

General consensus is that the new dashboard is more detailed and useful. Users would also use it more often because they can monitor changes over time. Historical contexts are extremely helpful in providing comparisons, promoting critical analysis, and making informed decisions.

Several charts are hard for some users to understand. Thus, short descriptions for each section are to be added to provide a simple explanation on what the information represents and how to read them. Another comment is on highlighting today's sales information as it is still the most important number of the day. Thus, the number is made bigger so that it can prominently catch users' glance. It is further enhanced by red or green colour to indicate the healthiness of the current sales. Red colour indicates that it is lower than the 4-week average figure while green means that it is equal or more than the average. This helps users to quickly know if the restaurant is doing well or needs further investigation.

In addition to showing items with low inventory level, some respondents asked to show the opposite which is the items with highest inventory level. These items are a cause of concern because they are sunk costs that need to be consumed in order to generate money. Owners and managers can plan to recommend dishes to customers or run a promotion to make use of these items. For the top selling and worst selling items, colours are changed to be different to easily distinguish between the two.

Based on the results and feedbacks above, the revised final dashboard design is shown in Figure 44 below.



	Meal Duration	Bill Amount (Baht)	Check Size per Customer(Baht)
Benchmark	1:01	501	231
Table 1	1:59:01	1,670	334
Table 4	1:30:01	250	250
Table 11	1:05:57	1,344	672
Table 20	48:48	480	240
Table 8	42:02	300	100

	Used Today	Remaining
Coke (can)	20	10
Water (bottle)	15	5
Beef	3.5 kg	1.2 kg
Fish	2 kg	1 kg
Meatball	1 kg	0.8 kg

	Used Today	Remaining
Blood	0	20
Sprite	1	45
Sprout	0 kg	2 kg
Eel	0.1 kg	4 kg
Icecream	0	30

Figure 44 Revised Final Dashboard Design

Chapter 5 Conclusion

5.1 Conclusion

The objective of this thesis is to design the business intelligence system for Point-of-Sales software in full-service restaurants. The case-study company was faced with the situation to improve its POS software in order to differentiate itself from competitors and also to discover new value proposition in order to attract and retain users.

Users would like to measure and know restaurant performance in order to improve operations and revenue to survive in the ever competitive restaurant industry. This presented a business case for the company to build a proper business intelligence system that can help restaurants know their current performance. To build the BI system for POS, there are 3 deliverables which are the selection of Key Performance Indicators, the dashboard mock-up, and the data warehouse design.

The first part is to select a list of KPIs that would reflect various dimensions of restaurant performance. Balanced scorecard is used to make sure the chosen KPIs cover both financial and non-financial aspects of restaurant performance. There are a variety of performance measures but not all are equally important and deserve a place on the dashboard. Thus, elimination is done based on various criteria such as POS capability constraints and availability of data in order to ensure that the final list of KPIs are feasible to calculate and practical to use.

The second part is to design the dashboard mock-up to visualise the selected list of KPIs effectively. Principles on visual perception, data relationships, and display media are applied in order to ensure that the resultant display is effective in communicating the information and that users can easily interpret and make use of the information to make better decisions. The KPIs are enriched by context and displayed in such a way to encourage critical analyses and better decision making. At this stage, data needed for

the calculation of KPIs and other contextual information are identified and hence, the design of data structure in the data warehouse can proceed.

The third part is to design the data structure of the data warehouse to ensure that all these information can be retrieved efficiently. Because the current database is based on OLTP architecture which is not ideal for data retrieval, a new data warehouse design based on dimensional modelling is required. Elements of dimensional data models namely, grain, dimension tables, and fact tables are specified based on the dashboard requirement. Dimension and fact tables are put together using the star schema and the physical data model is specified for future implementation.

The new design was validated by 20 respondents who are either owners or managers of full-service restaurants who have been using the case-study POS consistently for more than 6 months. They were asked to rate the current design and the new design on the scale of 1 to 10. Other feedback on the usefulness, satisfaction, and overall visual design were also collected in the face-to-face questionnaires. After that, Wilcoxon signed rank test is conducted to verify that the new design is indeed more useful and preferred by users than the current one.

This research is the first to present a systematic and practical approach in designing the BI system for POS software in restaurant industry. It focuses on the use of POS data and visualisation of information on a dashboard to show important restaurant performance measures. It studies many aspects including restaurant performance measures, visual display, and data warehouse design. The research produces deliverables that can be used by software developers to implement the actual system. With great ratings and reviews from respondents, the BI system with the new dashboard design is expected to help restaurant owners and managers manage their restaurants better and grow the business. It would also answer the company's goals to attract and retain users with a

new value proposition. All in all, the research drives the adoption of technology and analysis of data to enhance restaurant operations in Thailand.

5.2 Future Work

There are a lot more that POS and its data can do to help restaurant owners, managers, and staff improve overall restaurant management. This research is just a stepping stone for future work on this area. For next steps, several extensions can be done to further the studies.

- A dashboard for other types of restaurants such as buffet, cafes, fast food can be designed to capture more relevant performance measures
- Interactive dashboard that can be clicked to show more details for better decision making or link to relevant reports for deep-dives
- When more restaurants use the case-study POS and more data are collected, it would be possible to establish performance benchmarks for different types and sizes of restaurants in a particular area. Dashboard can present industry's benchmark as a contextual comparison, instead of own restaurant's average numbers as presented in this thesis. This would give a richer view of how a restaurant is doing compared with competitors of similar types in nearby areas.

As technologies progress and use of data advances, we would definitely see more researches and application of POS and its data in the field of restaurant operations.

REFERENCES

1keydata. (2019). Data Modeling - Conceptual, Logical, And Physical Data Models. Retrieved from https://www.1keydata.com/datawarehousing/data-modeling-levels.html

Abdillah, F., & Wira Diana, I. (2018). Balanced Scorecard Implementation in Restaurant Management. *E-Journal Of Tourism*, 30-39.

Alois, E. (2017). Calculate Your Table Turnover Rate. Retrieved from https://archive.lavu.com/blog/success-tips/calculate-your-table-turnover-rate.html

Ancill, R. (2016). Restaurant KPIs Explained. Retrieved from https://www.execrank.com/board-of-directors-articles/restaurant-kpis-explained

Balke, M. (2017). AARRR Framework- Metrics That Let Your StartUp Sound Like A Pirate Ship. Retrieved from https://medium.com/@ms.mbalke/aarrr-framework-metrics-that-let-your-startup-sound-like-a-pirate-ship-e91d4082994b

Datawarehouse4u. (2008a). Snowflake Schema. Retrieved from https://www.datawarehouse4u.info/Data-warehouse-schema-architecture-snowflake-schema.html

Datawarehouse4u. (2008b). Fact Constellation Schema. Retrieved from https://www.datawarehouse4u.info/Data-warehouse-schema-architecture-fact-constellation-schema.html

Eab group. (2011). Top 25 Restaurant KPIs of 2010. Retrieved from http://www.performancemagazine.org/wp-content/uploads/Top-25-Restaurant-KPIs-of-2010-smartKPIs-desktop.pdf

Eckerson, W.W. (2006). *Performance Dashboard: Measuring, Monitoring, and Managing Your Business.* John Wiley & Sons.

Few, S. (2004). Eenie, Meenie, Minie, Moe: Selecting the Right Graph for Your Message. Retrieved from https://www.perceptualedge.com/articles/ie/the_right_graph.pdf

Few, S. (2006). *Information Dashboard Design: The Effective Visual Communication of Data.* O'Reilly Media, Inc.

Few, S. (2010). Dashboard Design for at-a-glance monitoring. Retrieved from http://www.perceptualedge.com/files/Dashboard_Design_Course.pdf

Gangadharan, G.R. & Swami, S.N. (2004). Business intelligence systems: design and implementation strategies. *Proceedings of the 26th International Conference on Information Technology Interfaces, 1,* 139 - 144.

Gartner. (n.d.). Business Intelligence (BI). Retrieved from https://www.gartner.com/it-glossary/business-intelligence-bi/

Ghazisaeidi, M., Safdari, R., Torabi, M., Mirzaee, M., Farzi, J., & Goodini, A. (2015). Development of Performance Dashboards in Healthcare Sector: Key Practical Issues. *Acta informatica medica : AIM : journal of the Society for Medical Informatics of Bosnia & Herzegovina : casopis Drustva za medicinsku informatiku BiH,* 23(5), 317–321.

Interaction Design Foundation. (2018). Preattentive Visual Properties and How to Use Them in Information Visualization. Retrieved from https://www.interaction-design.org/literature/article/preattentive-visual-properties-and-how-to-use-them-in-information-visualization

Kaplan, R. S., & Norton, D. P. (1992). The balance scorecard – measures that drive performance. *Harvard Business Review, 70*(1), 71–79.

Kaplan, R. S., & Norton, D. P. (1996). Using the balance scorecard as a strategic management system. *Harvard Business Review, 74*(1), 75–85.

Kaplan, R. S., & Norton, D. P. (2001). *The strategy-focused organization: How balanced scorecard companies thrive in the new business environment.* Boston, MA: Harvard Business School Press

Karami M. (2014). A design protocol to develop radiology dashboards. *Acta informatica medica : AIM : journal of the Society for Medical Informatics of Bosnia & Herzegovina : casopis Drustva za medicinsku informatiku BiH, 22*(5), 341–346.

Kimball, R. & Ross, M. (2013). *The Data Warehouse Toolkit*. Wiley 3rd edition.

Kimes, S.E. (2004). Restaurant Revenue Management. *Cornell Hospitality Report, 4*(2), 5-34.

KResearch. (2017). Restaurant Strategies 2017. Retrieved from https://www.kasikornbank.com/th/business/sme/KSMEKnowledge/article/KSMEAnalysis/Documents/Restuarant-Strategies-2017.pdf

KResearch. (2018). Restaurant Business: Expected to Rise 4-5% in 2018. Retrieved from https://www.kasikornresearch.com/en/analysis/k-econ/business/Pages/36841.aspx

Lavu. (n.d.). Food Truck POS System. Retrieved from https://www.lavu.com/food-truck-point-sale-system-pos

Liu, S. & Chen, C. (2013). Balanced Scorecard in Hospitality, *Seventh International Conference on Complex, Intelligent, and Software Intensive Systems,* 667-672.

Loyverse. (n.d.). Loyverse Dashboard Features. Retrieved from https://loyverse.com/dashboard

Oetting, J. (2018). Data Visualization 101: How to Choose the Right Chart or Graph for Your Data. Retrieved from https://blog.hubspot.com/marketing/types-of-graphs-for-data-visualization

Olszak, C.M. & Ziemba, E. (2007). Approach to Building and Implementing Business Intelligence Systems. *Interdisciplinary Journal of Information, Knowledge, and Management, 2*, 135-148.

POS Central. (n.d.). Casio TK3200 Cash Register. Retrieved from https://www.poscentral.com.au/casio-tk3200-cash-register.html

Safdari, R., Ghazisaeedi, M., Mirzaee, M., Farzi, J. & Goodini, A. (2014). Development of balanced key performance indicators for emergency departments strategic dashboards following analytic hierarchical process. *The Health Care Manager, 33*(4), 328–334.

Schneider, M. (2008). A general model for the design of data warehouses. *International Journal of Production Economics, Elsevier, 112*(1), 309-325.

Square. (2018). SQUARE ANALYTICS. Retrieved from https://squareup.com/pos/dashboard/analytics

Tayal, M. (2012). Star schema in database: Guide to construction and composition. Retrieved from https://www.computerweekly.com/tutorial/Star-schema-in-database-Guide-to-construction-and-composition

Tetreault, A. (2017). Food Cost Formula: How to Calculate Food Cost Percentage. Retrieved from https://pos.toasttab.com/blog/how-to-calculate-food-cost-percentage.

Tokola, H., Gröger, C., Järvenpää, E. & Niemi, E. (2016). Designing Manufacturing Dashboards on the Basis of a Key Performance Indicator Survey. *Procedia CIRP, 57*, 619-624.

Tufte, E.R. (1983). *The Visual Display of Quantitative Information.* Cheshire: Graphic Press. Cheshire, Connecticut.

Vilarinho, S., Lopes, I. & Sousa, S. (2017). Design Procedure to Develop Dashboards Aimed at Improving the Performance of Productive Equipment and Processes. *Procedia Manufacturing. 11*, 1634-1641.

Wakai, A., O'Sullivan, R., Staunton, P., Walsh, C., Hickey, F. & Plunkett, P.K. (2013). Development of key performance indicators for emergency departments in Ireland using an electronic modified-Delphi consensus approach. *European Journal of Emergency Medicine, 20*, 109–114.

Ware, C. (2004). *Information Visualization: Perception for Design* (2nd ed.). San Francisco: Morgan Kaufmann.

Wongnai. (n.d.). Reports. Retrieved from https://www.wongnai.com/pos/features

Yigitbasioglu, O.M. & Velcu, O. (2012). A review of dashboards in performance management: Implications for design and research, *International Journal of Accounting Information Systems, 13*(1), 41-59.

Zeisig, K. (2018). 12 sales metrics to kick-start your sales analytics. Retrieved from https://www.klipfolio.com/blog/sales-analytics-12-metrics

Zelazny, G. (2001). *Say It With Charts: The Executive's Guide to Visual Communication (4th ed.)*. McGraw-Hill.

APPENDICES

Appendix A Participant Information Leaflet (English)

Participant Information Leaflet

Design of Business Intelligence System for Point-of-Sales Software in Full-Service Restaurants

Invitation to participate in a survey

We would like to invite you to join our research survey that is as part of the requirement to for a completion of Master Degree from University of Warwick. Before you make a decision, it is important for you to understand why the survey is being carried out, and what it will involve. Please take your time to read the following information carefully and ask questions if there is anything that is not clear or if you would like more information.

What is the purpose of the survey?

The purpose of this survey is to find out the overall satisfaction of the current dashboard design of the case study's Point-of-Sales you are using. It is also to introduce you to a new design and ask you to rate the overall satisfaction of the new design. Your opinions on the new design will also be collected to make further improvement to the design.

Why have I been chosen?

You have been chosen because you are the owner or manager of a full-service restaurant. You have been using the case study's POS for more than 6 months, including the dashboard function. Your restaurant is active and located in Bangkok.

Do I have to take part?

No. It is up to you to decide whether you would like to take part in this survey. If you decide to not take part in the survey, then you can stop it at any time. A decision to

withdraw from the survey at any time or a decision not to take part in the survey will not have any consequences on the product and quality of service you are receiving from the case study company.

How do I consent to take part in the survey?

An electronic consent form will be given prior to the start of the survey. If you confirm and go into the survey, then we will assume that you have provided your consent to take part in it.

What will the survey involve if I take part?

If you take part in the survey, you will be asked a series of questions about satisfaction level of the current and new dashboard design and usefulness. It should take approximately 15 minutes to complete.

What are the possible disadvantages or risks of taking part in the survey?

Participating in the research is not anticipated to cause you any disadvantages or discomfort.

What are the possible benefits of taking part in the survey?

Whilst there is no immediate benefit for the participants. Your valuable opinions will be used to adjust the design of the dashboard and make it more useful for you to grow your business and make restaurant operations more efficient.

Will my taking part in this survey be kept confidential?

Yes. All of the information we collect about you will be anonymised using a unique identification number so that it will not be possible to identify you from any of your information. Your data will be stored using this unique identification number and not your contact details (i.e. names or addresses) so that you cannot be identified from it. All data will be kept strictly confidential, and will only be seen by the researcher.

Any data collected about you in the online questionnaire will be stored online in a form accessible by only the research and protected by passwords. Data collected may be shared in an anonymised form or at aggregate level to allow reuse by the research team and other third parties. These anonymised or aggregate data will not allow any individuals or their restaurants to be identified or identifiable.

What will happen to the results of the survey?

At the end of the study, we will analyse all of the survey results including your and other participants' inputs. The research will be submitted to the University's examination committee for evaluation. We might then publish our findings in an academic journal and at relevant conferences. You will not be identified in any publication arising from this survey.

Will I be recorded, and how will the recorded media be used?

You will not be recorded in any way other than your input to the questionnaire without separate permission being gained from you.

Who has ethically reviewed the research?

The research has been ethically approved by the Overseas Programmes Course Office, Warwick Manufacturing Group.

Contacts for further information

Lalida Chunhasomboon

Email: Lalida.chunhasomboon@warwick.ac.uk

Thank you for taking part in this research.

Appendix B Participant Information Leaflet (Thai)

ข้อมูลสำหรับผู้เข้าร่วมโครงการวิจัย

การออกแบบระบบวิเคราะห์ข้อมูลทางธุรกิจสำหรับโปรแกรมจัดการหน้าร้านในร้านอาหารประเภทบริการครบวงจร

ขอเรียนเชิญเข้าร่วมโครงการวิจัย

โครงการวิจัยนี้เป็นส่วนหนึ่งของข้อกำหนดในการสำเร็จการศึกษาระดับปริญญาโทจาก University of Warwick ก่อนที่ท่านจะตอบแบบสำรวจ สิ่งสำคัญคือท่านจะต้องเข้าใจว่าเหตุใดจึงต้องทำการสำรวจและท่านมีส่วนเกี่ยวข้องอย่างไร โปรดสละเวลาในการอ่านข้อมูลต่อไปนี้อย่างระมัดระวังและสอบถามหากมีสิ่งใดไม่ชัดเจน หรือหากท่านต้องการข้อมูลเพิ่มเติม

วัตถุประสงค์ในการการสำรวจ

วัตถุประสงค์ในการสำรวจนี้ เพื่อหาความพึงพอใจโดยรวมของการออกแบบ แดชบอร์ด ที่ท่านใช้ในปัจจุบัน และแนะนำ แดชบอร์ด ที่ออกแบบใหม่มาให้ใช้ เพื่อให้ท่านให้คะแนนความพึงพอใจโดยรวมของแดชบอร์ดที่ออกแบบใหม่ ความคิดเห็นของท่านเกี่ยวกับการออกแบบใหม่จะถูกรวบรวมเพื่อปรับปรุงการออกแบบต่อไป

ทำไมท่านจึงถูกเลือก

ท่านได้รับเลือกเพราะท่านเป็นเจ้าของหรือผู้จัดการร้านอาหารบริการเต็มรูปแบบ คุณใช้ POS และศึกษามานานกว่า 6 เดือนรวมถึงฟังก์ชั่นการใช้งานของ แดชบอร์ด และร้านอาหารของท่านเปิดให้บริการและตั้งอยู่ในเขตกรุงเทพมหานคร

ท่านจำเป็นต้องเข้าร่วมโครงการวิจัยหรือไม่

ขึ้นอยู่กับท่านที่จะตัดสินใจว่าต้องการมีส่วนร่วมในแบบสำรวจนี้หรือไม่ เมื่อท่านตัดสินใจมีส่วนร่วมในการสำรวจแล้ว ท่านสามารถถอนตัวจากการสำรวจเมื่อใดก็ได้ หรือตัดสินใจที่จะไม่เข้าร่วมในการสำรวจก็ได้ ทั้งนี้จะไม่มีผลกระทบใดๆ ต่อผลิตภัณฑ์และคุณภาพของการบริการที่ท่านจะได้รับจากบริษัทฯกรณีศึกษา

ท่านจะยินยอมและมีส่วนร่วมในการสำรวจได้อย่างไร

ท่านจะได้รับแบบฟอร์มความยินยอมทางอิเล็กทรอนิกส์ก่อนที่จะเริ่มการสำรวจ เมื่อท่านยืนยันเข้าร่วมการสำรวจ จึงจะถือว่าท่านให้ความยินยอมร่วมสำรวจในครั้งนี้

การสำรวจเกี่ยวข้องกับอะไรบ้าง

การสำรวจจะเป็นคำถามเกี่ยวกับ ระดับความพึงพอใจของการออกแบบและประโยชน์ของแดชบอร์ด ที่ใช้อยู่ในปัจจุบันและแบบใหม่ ใช้เวลาตอบแบบสำรวจประมาณ 15 นาที

การมีส่วนร่วมในการสำรวจจะมีข้อเสียหรือความเสี่ยงหรือไม่

การมีส่วนร่วมในการวิจัยจะไม่มีข้อเสียหรือความเสี่ยงใดที่จะทำให้ท่านเสียเปรียบหรือไม่สบายใจ

ประโยชน์ที่จะได้รับจากการเข้าร่วมในการสำรวจ

ประโยชน์สำหรับการเข้าร่วมสำรวจจะไม่เกิดขึ้นทันที แต่ความคิดเห็นที่มีค่าของท่านจะถูกใช้เพื่อปรับปรุงการออกแบบแดชบอร์ดและทำให้มีประโยชน์มากขึ้นเพื่อให้ท่านใช้ในการขยายธุรกิจ และทำให้การดำเนินงานของร้านอาหารมีประสิทธิภาพมากขึ้น

การมีส่วนร่วมในแบบสำรวจนี้ จะถูกเก็บเป็นความลับ

ข้อมูลที่ได้รับจากท่านทั้งหมดจะเก็บรวบรวมโดยไม่ระบุชื่อ แต่จะใช้เลขประจำตัวที่ไม่ซ้ำกัน ดังนั้นจึงไม่สามารถระบุตัวตนจากข้อมูลของท่านได้ ข้อมูลของท่านจะถูกเก็บไว้ โดยใช้เลขประจำตัวที่ไม่ซ้ำกัน และไม่มีข้อมูลการติดต่อของท่าน (เช่น ชื่อ ,ที่อยู่) ข้อมูลของท่านทั้งหมดจะถูกเก็บเป็นความลับอย่างเคร่งครัดและจะใช้ข้อมูลได้เฉพาะผู้วิจัยเท่านั้น

ข้อมูลใด ๆ ที่รวบรวมเกี่ยวกับท่านในแบบสอบถามออนไลน์จะถูกจัดเก็บออนไลน์ในรูปแบบที่เข้าถึงได้โดยการวิจัยและป้องกันด้วยรหัสผ่านเท่านั้น ข้อมูลที่เก็บรวบรวมอาจใช้ร่วมกันในรูปแบบที่ไม่เปิดเผยชื่อ หรือในรูปแบบข้อมูลรวมเพื่อให้ทีมวิจัยและบุคคลที่สามอื่นๆนำมาใช้ซ้ำได้ ข้อมูลที่ไม่เปิดเผยชื่อ หรือข้อมูลรวมเหล่านี้จะไม่อนุญาตให้บุคคลอื่นใดหรือร้านอาหารใดนำข้อมูลไปใช้ได้

ผลของการสำรวจ

เราจะนำผลการสำรวจของผู้ร่วมโครงการทั้งหมดมาวิเคราะห์เป็นผลของการวิจัยและจะส่งไปยังคณะกรรมการตรวจสอบของมหาวิทยาลัยเพื่อการประเมินผล อาจมีการเผยแพร่ผลการวิจัยของ

เราในวารสารทางวิชาการและในการประชุมที่เกี่ยวข้อง ท่านจะไม่ถูกระบุชื่อในสิ่งพิมพ์ใดๆจากการสำรวจครั้งนี้

การบันทึกและการใช้สื่อที่บันทึก

ท่านจะไม่ถูกบันทึกในทางอื่นใดนอกจากการป้อนข้อมูลของท่านไปยังแบบสอบถามเท่านั้น

ใครบ้างที่ตรวจสอบงานวิจัย

การวิจัยได้รับการอนุมัติทางจริยธรรมจาก สำนักงานหลักสูตรต่างประเทศของกลุ่ม Warwick Manufacturing Group

สอบถามข้อมูลเพิ่มเติมได้ที่
นางสาว ลลิดา ชุณหสมบูรณ์
อีเมล: Lalida.chunhasomboon@warwick.ac.uk

ขอบคุณที่เข้าร่วมการวิจัยครั้งนี้

Appendix C Consent Form (English)

Consent Form

Clicking on “Agree” button indicates that

1. You have read and understood the Participant Information Leaflet dated 11 April 2019 (version 1.0) for the above study. You have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

2. You understand that your participation is voluntary and that you are free to withdraw at any time without giving any reason, or legal rights being affected.

3. You agree to take part in the above study.

If you do not wish to participate in this survey, please do not proceed to the next section. You can inform the researcher of your intention to withdraw.

Initials of Participant: _____

Date: _____

Appendix D Consent Form (Thai)

แบบฟอร์มการให้ความยินยอม

การคลิกปุ่ม "เห็นด้วย" เป็นการยินยอมตามข้อตกลงดังนี้

1. ท่านได้อ่านและทำความเข้าใจข้อมูลผู้เข้าร่วมโครงการวิจัย ลงวันที่ 11 เมษายน 2562 (รุ่น 1.0) แล้ว โดยได้พิจารณาข้อมูลและสอบถามข้อสงสัย รวมถึงได้รับคำตอบเป็นที่น่าพึงพอใจ

2. ท่านเข้าใจว่าการที่ ท่านมีส่วนร่วมเป็นอาสาสมัคร ท่านมีอิสระที่จะถอนตัวได้ตลอดเวลา โดยไม่ต้องให้เหตุผล หรือสิทธิทางกฎหมาย และไม่มีผลกระทบใดๆกับท่าน

ท่าน ตกลงที่จะมีส่วนร่วมในโครงการวิจัยข้างต้น

หากท่านไม่ต้องการมีส่วนร่วมในแบบสอบถามนี้ โปรดอย่าดำเนินการในส่วนถัดไป ท่านสามารถแจ้งให้นักวิจัยทราบที่จะถอนตัวไม่เข้าร่วมโครงการได้

ชื่อของผู้เข้าร่วม: _____

วันที่ : _____

Appendix E Questionnaire (Thai)

แบบสอบถามความพึงพอใจต่อการแสดงผลบน Dashboard ปัจจุบัน

คำชี้แจง: แบบสอบถามชุดนี้เป็นส่วนหนึ่งของการวิจัยเพื่อการศึกษาระดับปริญญาโท คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ดังนั้น จึงใคร่ขอความร่วมมือจากท่านในการตอบแบบสอบถามชุดนี้ทุกข้อตามความเป็นจริง เพื่อเป็นประโยชน์ในการทำงานวิจัย
ทั้งนี้ข้อมูลส่วนตัวและคำตอบของท่านจะถูกเก็บไว้เป็นความลับทั้งหมด

* Required

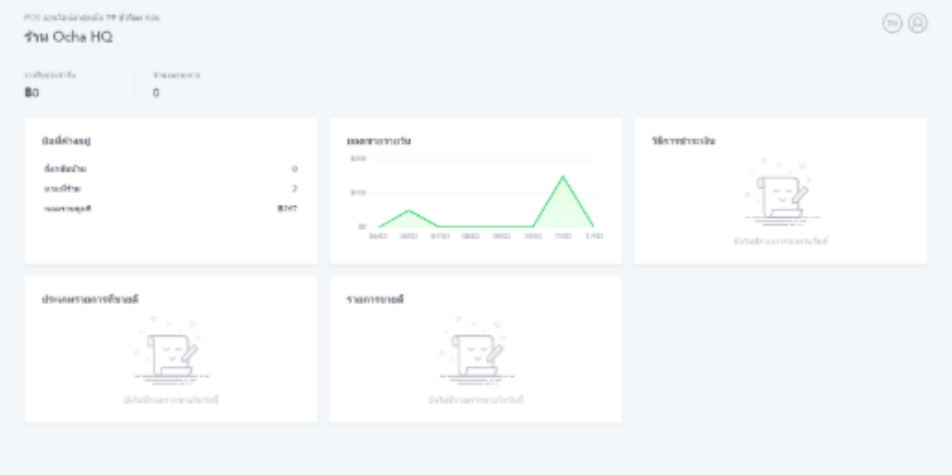
ตำแหน่ง *

- ◯ เจ้าของร้าน
- ◯ ผู้จัดการร้าน
- ◯ พนักงานร้าน

ขนาดร้าน *

- ◯ เล็ก (1-10 โต๊ะ)
- ◯ กลาง (11-30 โต๊ะ)
- ◯ ใหญ่ (31 โต๊ะขึ้นไป)

คะแนนความพึงพอใจของ Dashboard เก่า



	1	2	3	4	5	6	7	8	9	10	
ไม่พึงพอใจ	○	○	○	○	○	○	○	○	○	○	พึงพอใจสุงสุด

NEXT

Page 1 of 2

Never submit passwords through Google Forms.

แบบสอบถามความพึงพอใจและประโยชน์ที่ได้รับจากการแสดงผลบน Dashboard แบบใหม่

การบ่งบอกสถานการณ์ปัจจุบันของร้าน *

	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่มีความเห็น	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
แสดงสถานการณ์ปัจจุบันโดยรวมของร้าน	○	○	○	○	○
แสดงการเปลี่ยนแปลงที่เกิดขึ้นระหว่างวัน	○	○	○	○	○
แสดงความผิดปกติที่เกิดขึ้นในร้าน เช่น มีการยกเลิกบิลเป็นจำนวนมาก, การนั่งโต๊ะนาน	○	○	○	○	○
แสดงถึงการใช้งานโต๊ะที่นั่งภายในร้าน	○	○	○	○	○

การบ่งบอกข้อมูลเชิงการเงิน *

	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่มีความเห็น	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
แสดงข้อมูลเชิงการเงินที่มีประโยชน์	○	○	○	○	○
มีการเปรียบเทียบข้อมูลที่เหมาะสมและเพียงพอ	○	○	○	○	○
สามารถนำข้อมูลไปใช้ประโยชน์ต่อการตัดสินใจ	○	○	○	○	○

การบ่งบอกข้อมูลเชิงลูกค้า *

	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่มีความเห็น	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
แสดงข้อมูลเชิงลูกค้าที่มีประโยชน์	○	○	○	○	○
มีการเปรียบเทียบข้อมูลที่เหมาะสมและเพียงพอ	○	○	○	○	○
สามารถนำข้อมูลไปใช้ประโยชน์ต่อการตัดสินใจ	○	○	○	○	○

การบ่งบอกข้อมูลเชิงการทำงานภายใน *

	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่มีความเห็น	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
แสดงข้อมูลเชิงการทำงานที่มีประโยชน์	○	○	○	○	○
มีการเปรียบเทียบข้อมูลที่เหมาะสมและเพียงพอ	○	○	○	○	○
สามารถนำข้อมูลไปใช้ประโยชน์ต่อการตัดสินใจ	○	○	○	○	○

ความพึงพอใจต่อการแสดงผล dashboard *

ความพึงพอใจต่อการแสดงผลและแบ่งหมวดหมู่และจัดเรียงหน้า Dashboard โดยรวม

	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่มีความเห็น	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
การแบ่งหมวดหมู่ทำให้ค้นหาข้อมูลได้ง่าย	○	○	○	○	○
การใช้สื่อเช่น กราฟ, ตาราง มีความเหมาะสม ทำให้เข้าใจง่ายและรวดเร็ว	○	○	○	○	○
หน้าจอมีความสวยงาม เหมาะสมและน่าสนใจ	○	○	○	○	○
สีที่ใช้มีความเหมาะสม	○	○	○	○	○
ตัวอักษรและขนาดที่ใช้มีความเหมาะสม	○	○	○	○	○

การตัดสินใจและแผนปรับปรุงเพื่อเพิ่มประสิทธิภาพการทำงานของร้าน *

เมื่อนำข้อมูลทุกส่วนมาประกอบกัน ท่านสามารถทำการตัดสินใจเปลี่ยนแปลงหรือแก้ไขเพื่อเพิ่มรายได้และประสิทธิภาพการทำงานของร้านได้ขนาดไหน

	เห็นด้วยอย่างยิ่ง	เห็นด้วย	ไม่มีความเห็น	ไม่เห็นด้วย	ไม่เห็นด้วยอย่างยิ่ง
ช่วยในการปรับปรุงแก้ไขสถานการณ์ปัจจุบันได้	○	○	○	○	○
ช่วยวางแผนหรือตัดสินใจเพื่อเพิ่มรายได้	○	○	○	○	○
ช่วยจัดการลูกค้าได้ดียิ่งขึ้น	○	○	○	○	○
ช่วยจัดการการใช้งานโต๊ะให้มีประสิทธิภาพมากยิ่งขึ้น	○	○	○	○	○
ช่วยจัดการสินค้าและวัตถุดิบให้มีประสิทธิภาพมากยิ่งขึ้น	○	○	○	○	○
ช่วยติดตามผลลัพธ์ของการเปลี่ยนแปลงหรือการแก้ไขได้ดียิ่งขึ้น	○	○	○	○	○

คะแนนความพึงพอใจของ Dashboard ใหม่ *

	1	2	3	4	5	6	7	8	9	10	
ไม่พึงพอใจ	○	○	○	○	○	○	○	○	○	○	พึงพอใจสูงสุด

ท่านคิดว่าท่านจะใช้ Dashboard นี้ประมานกี่ครั้งต่อวัน

○ 1-2 ครั้ง

○ 3-5 ครั้ง

โปรดแสดงความคิดเห็นหรือข้อเสนอแนะอื่นๆเพื่อปรับปรุงพัฒนาระบบในอนาคต

Your answer

BACK SUBMIT Page 2 of 2

Never submit passwords through Google Forms.

Appendix F Critical Values in Wilcoxon Signed Rank Test

Table XIII Critical Values of T_0 in the Wilcoxon Paired Difference Signed Rank Test

One-Tailed	Two-Tailed	$n = 5$	$n = 6$	$n = 7$	$n = 8$	$n = 9$	$n = 10$
$\alpha = .05$	$\alpha = .10$	1	2	4	6	8	11
$\alpha = .025$	$\alpha = .05$		1	2	4	6	8
$\alpha = .01$	$\alpha = .02$			0	2	3	5
$\alpha = .005$	$\alpha = .01$				0	2	3
		$n = 11$	$n = 12$	$n = 13$	$n = 14$	$n = 15$	$n = 16$
$\alpha = .05$	$\alpha = .10$	14	17	21	26	30	36
$\alpha = .025$	$\alpha = .05$	11	14	17	21	25	30
$\alpha = .01$	$\alpha = .02$	7	10	13	16	20	24
$\alpha = .005$	$\alpha = .01$	5	7	10	13	16	19
		$n = 17$	$n = 18$	$n = 19$	$n = 20$	$n = 21$	$n = 22$
$\alpha = .05$	$\alpha = .10$	41	47	54	60	68	75
$\alpha = .025$	$\alpha = .05$	35	40	46	52	59	66
$\alpha = .01$	$\alpha = .02$	28	33	38	43	49	56
$\alpha = .005$	$\alpha = .01$	23	28	32	37	43	49
		$n = 23$	$n = 24$	$n = 25$	$n = 26$	$n = 27$	$n = 28$
$\alpha = .05$	$\alpha = .10$	83	92	101	110	120	130
$\alpha = .025$	$\alpha = .05$	73	81	90	98	107	117
$\alpha = .01$	$\alpha = .02$	62	69	77	85	93	102
$\alpha = .005$	$\alpha = .01$	55	61	68	76	84	92
		$n = 29$	$n = 30$	$n = 31$	$n = 32$	$n = 33$	$n = 34$
$\alpha = .05$	$\alpha = .10$	141	152	163	175	188	201
$\alpha = .025$	$\alpha = .05$	127	137	148	159	171	183
$\alpha = .01$	$\alpha = .02$	111	120	130	141	151	162
$\alpha = .005$	$\alpha = .01$	100	109	118	128	138	149
		$n = 35$	$n = 36$	$n = 37$	$n = 38$	$n = 39$	
$\alpha = .05$	$\alpha = .10$	214	228	242	256	271	
$\alpha = .025$	$\alpha = .05$	195	208	222	235	250	
$\alpha = .01$	$\alpha = .02$	174	186	198	211	224	
$\alpha = .005$	$\alpha = .01$	160	171	183	195	208	
		$n = 40$	$n = 41$	$n = 42$	$n = 43$	$n = 44$	$n = 45$
$\alpha = .05$	$\alpha = .10$	287	303	319	336	353	371
$\alpha = .025$	$\alpha = .05$	264	279	295	311	327	344
$\alpha = .01$	$\alpha = .02$	238	252	267	281	297	313
$\alpha = .005$	$\alpha = .01$	221	234	248	262	277	292
		$n = 46$	$n = 47$	$n = 48$	$n = 49$	$n = 50$	
$\alpha = .05$	$\alpha = .10$	389	408	427	446	466	
$\alpha = .025$	$\alpha = .05$	361	379	397	415	434	
$\alpha = .01$	$\alpha = .02$	329	345	362	380	398	
$\alpha = .005$	$\alpha = .01$	307	323	339	356	373	

Source: From F. Wilcoxon and R. A. Wilcox, "Some Rapid Approximate Statistical Procedures," 1964, p. 28.

VITA

NAME	Lalida Chunhasomboon
DATE OF BIRTH	07 July 1991
PLACE OF BIRTH	Bangkok
INSTITUTIONS ATTENDED	National University of Singapore
HOME ADDRESS	5/127 Tiwanon Road Banmai Pakkred Nonthaburi Thailand 11120