THE FRAMEWORK OF IMPROVING ON-SITE MATERIALS TRACKING FOR INVENTORY MANAGEMENT PROCESS IN CONSTRUCTION PROJECTS

SITI RADZIAH BINTI LIWAN

A project report submitted in partial fulfilment of the requirement for the award of the Degree of Master of Technology Management.

Faculty of Technology Management and Business
Universiti Tun Hussein Onn Malaysia

August 2015
Inventory management is important especially in construction projects because materials and components constitute 50-60% of the total project cost. While inventory management has increased concerned among various parties within the project, materials tracking for inventory management also act the same way. Material tracking could provide timely information on materials availability and enables real-time on-site measurement of the project performance which is important for inventory management. However, material tracking practices in construction projects has been using manual method and it has many drawbacks. Although the application of advanced technology is needed as it has ability to assist materials tracking, however; there is still lack of materials tracking framework for inventory management process in construction projects. Therefore, the research aims to fill in this gap by developing an on-site material tracking framework for improving inventory management processes in Malaysian construction projects. In this research, potential implementation of RFID technology for materials tracking and the existing material tracking practices in construction projects were identified. Literature review and case studies approach were conducted to obtain data of the research. Ten case studies was undertaken to investigate inventory management process and material tracking practices in Malaysia construction projects. The data analysis involves both within case analysis and cross-case analysis. The findings conclude by developing an on-site material tracking framework for inventory management process which consists of seven components namely; manufacturing, materials delivery, materials arrival, materials storage, materials use, on-site control centre and report generation. The framework would be beneficial for contractors having intention to adopt RFID technology to assist and facilitate materials tracking particularly at the site storage area.
ABSTRAK

CONTENTS

TITLE i

DECLARATION ii

ACKNOWLEDGEMENT iii

ABSTRACT iv

CONTENTS vi

LIST OF TABLES xi

LIST OF FIGURES xii

LIST OF SYMBOLS AND ABBREVIATIONS xiii

CHAPTER 1 INTRODUCTION 1

1.1 Research Background 1
1.2 Problem Statement 3
1.3 Research Questions 5
1.4 Aim and Objectives 5
1.5 Scope of the Research 5
1.6 Research Methodology 6
1.7 Significance of the Research 9
1.8 Structure of the Thesis 9
1.9 Summary 10

CHAPTER 2 MATERIALS TRACKING FOR INVENTORY 11
MANAGEMENT PROCESS

2.1 Introduction 11
2.2 Inventory 11
2.2.1 Definitions of Inventory 12
2.2.2 The Importance of Inventory

2.3 Inventory Management Processes
2.3.1 Planning
2.3.2 Purchasing
2.3.3 Materials Delivery
2.3.4 Storage
2.3.5 Materials Issue

2.4 Inventory Management in Construction Projects

2.5 Inventory Management Problems

2.6 Material Tacking for Inventory Management
2.6.1 The Importance of Material Tracking
2.6.2 Current Approaches of Materials Tracking
2.6.3 Materials Tracking Technology
2.6.3.1 Bar-coding
2.6.3.2 Radio Frequency Identification (RFID)
2.6.3.3 Global Positioning System (GPS)
2.6.4 Benefits of ICT for Materials Tracking

2.7 RFID Technology for Materials Tracking
2.7.1 RFID Technology Application
2.7.2 RFID Components
2.7.2.1 RFID Tags
2.7.2.2 RFID Readers
2.7.3 The Advantages of RFID Technology
2.7.4 RFID for Materials Tracking in Construction Projects
2.7.5 Issues in RFID Implementation
2.7.5.1 Costs
2.7.5.2 Standardisation
2.7.6 Current RFID Situations in Malaysia

2.8 Potential Implementation of RFID for Materials Tracking in Malaysian Construction Projects

2.9 Several Materials Tracking Framework
2.9.1 Automated Project Schedule and Inventory Monitoring Framework
2.9.2 Real-time Materials Tracking Framework  
2.9.3 Ubiquitous Tracking and Locating of Construction Resources using GPS, GIS and RFID  
2.9.4 RFID-facilitated Construction Materials Management (RFID-CMM) Framework  
2.9.5 Integrating RFID, GPS and GPRS for Real-time Data Collection  
2.9.6 Information Lifecycle Management Framework for Material Control on Construction Sites  
2.10 Discussion of Materials Tracking Framework  
2.11 Theoretical Framework for On-Site Materials Tracking  
2.12 Summary 

CHAPTER 3 RESEARCH METHODOLOGY  
3.1 Introduction  
3.2 Introduction to Research  
3.3 Research Philosophy  
3.4 Research Approaches  
3.4.1 Quantitative Research  
3.4.2 Qualitative Research  
3.4.2.1 Case Studies  
3.5 Research Strategy Decision  
3.5.1 Selection of Research Methodology  
3.5.2 Selection of Multiple Case Studies and Interview Techniques  
3.5.2.1 Multiple Case Studies  
3.5.2.2 Interview Technique  
3.6 The Methods Adopted for this Research  
3.6.1 Literature Review  
3.6.2 Case Studies  
3.6.2.1 Selection of Respondents  
3.6.3 Framework Development  
3.7 Summary
CHAPTER 4 DATA ANALYSIS AND FINDINGS

4.1 Introduction

4.2 Objectives of Case Studies

4.3 Case Studies Projects
   4.3.1 Case A: Agricultural Complex Development
   4.3.2 Case B: School Development Project
   4.3.3 Case C: Residential Development Project
   4.3.4 Case D: Hypermarket Development Project
   4.3.5 Case E: Condominium Development
   4.3.6 Case F: Residential Development Project
   4.3.7 Case G: Public Infrastructure Development
   4.3.8 Case H: Residential Development Project
   4.3.9 Case I: Public Institution Development
   4.3.10 Case J: Public Secondary School

4.4 Key Findings from Case Studies
   4.4.1 Inventory Management Process
   4.4.2 Problems in Materials Tracking
   4.4.3 Materials Tracking Technology for Inventory Management
   4.4.4 Improving Materials Tracking for Inventory Management
   4.4.5 Integration of Inventory Management and Resource Modelling

4.5 Requirement for Real-Time Materials Tracking for Inventory Management Framework

4.6 Summary

CHAPTER 5 ON-SITE MATERIALS TRACKING FRAMEWORK FOR INVENTORY MANAGEMENT

5.1 Introduction

5.2 On-Site Materials Tracking Framework for
    Inventory Management- Components
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Research Objectives and Chapter Outcome</td>
<td>5</td>
</tr>
<tr>
<td>2.1</td>
<td>Summary of Inventory Management in Construction Projects</td>
<td>18</td>
</tr>
<tr>
<td>2.2</td>
<td>Inventory Management Problems in Construction Projects</td>
<td>19</td>
</tr>
<tr>
<td>2.3</td>
<td>Application of RFID Technology in Construction</td>
<td>27</td>
</tr>
<tr>
<td>2.4</td>
<td>Active versus Passive RFID Tags</td>
<td>34</td>
</tr>
<tr>
<td>2.5</td>
<td>RFID Tags Common Frequencies and their Uses</td>
<td>34</td>
</tr>
<tr>
<td>2.6</td>
<td>Summary of Materials Tracking Framework</td>
<td>57</td>
</tr>
<tr>
<td>3.1</td>
<td>Selection of Research Methodologies</td>
<td>61</td>
</tr>
<tr>
<td>3.2</td>
<td>Qualitative versus Quantitative Research</td>
<td>64</td>
</tr>
<tr>
<td>3.3</td>
<td>Comparison of Qualitative and Quantitative Data</td>
<td>67</td>
</tr>
<tr>
<td>3.4</td>
<td>Relevant Situation for Different Research Strategies</td>
<td>70</td>
</tr>
<tr>
<td>3.5</td>
<td>Project and Respondent Background</td>
<td>80</td>
</tr>
<tr>
<td>4.1</td>
<td>Project and Respondent Background</td>
<td>90</td>
</tr>
<tr>
<td>4.2</td>
<td>Summary of Cross-case Analysis</td>
<td>126</td>
</tr>
<tr>
<td>4.3</td>
<td>Inventory Management Process</td>
<td>129</td>
</tr>
<tr>
<td>4.4</td>
<td>Problems in Materials Tracking</td>
<td>134</td>
</tr>
<tr>
<td>4.5</td>
<td>The Application of Technology for Materials Tracking</td>
<td>136</td>
</tr>
<tr>
<td>4.6</td>
<td>Factors Improving Current Material Tracking Practices</td>
<td>140</td>
</tr>
<tr>
<td>4.7</td>
<td>The Integration Process</td>
<td>143</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>The Research Process Flow Chart</td>
<td>7</td>
</tr>
<tr>
<td>2.1</td>
<td>Bar-coding Label</td>
<td>24</td>
</tr>
<tr>
<td>2.2</td>
<td>Typical RFID-based System</td>
<td>31</td>
</tr>
<tr>
<td>2.3</td>
<td>Active and Passive RFID Tags</td>
<td>33</td>
</tr>
<tr>
<td>2.4</td>
<td>Handheld Reader</td>
<td>35</td>
</tr>
<tr>
<td>2.5</td>
<td>Materials Tracking using RFID Reader</td>
<td>39</td>
</tr>
<tr>
<td>2.6</td>
<td>Automated Project Schedule and Inventory Monitoring Process</td>
<td>45</td>
</tr>
<tr>
<td>2.7</td>
<td>Real-time Materials Tracking Framework</td>
<td>46</td>
</tr>
<tr>
<td>2.8</td>
<td>Automatic Data Collection System</td>
<td>48</td>
</tr>
<tr>
<td>2.9</td>
<td>RFID-facilitated CMM System</td>
<td>50</td>
</tr>
<tr>
<td>2.10</td>
<td>Automatic Data Collection using RFID, GPS and GPRS</td>
<td>52</td>
</tr>
<tr>
<td>2.11</td>
<td>A Conceptual ILM Framework for Material Control</td>
<td>53</td>
</tr>
<tr>
<td>2.12</td>
<td>Theoretical Framework for On-Site Materials Tracking</td>
<td>58</td>
</tr>
<tr>
<td>3.1</td>
<td>Selection of Research Methodology</td>
<td>62</td>
</tr>
<tr>
<td>3.2</td>
<td>Quantitative Research Process</td>
<td>65</td>
</tr>
<tr>
<td>3.3</td>
<td>Qualitative Research Process</td>
<td>66</td>
</tr>
<tr>
<td>3.4</td>
<td>Basic Types of Designs for Case Studies</td>
<td>73</td>
</tr>
<tr>
<td>3.5</td>
<td>Case Study Method</td>
<td>74</td>
</tr>
<tr>
<td>3.6</td>
<td>The Overall Research Process</td>
<td>77</td>
</tr>
<tr>
<td>5.1</td>
<td>On-Site Materials Tracking Framework for Inventory Management</td>
<td>151</td>
</tr>
<tr>
<td>5.2</td>
<td>Materials Storage Process</td>
<td>156</td>
</tr>
<tr>
<td>5.3</td>
<td>Materials Use Process</td>
<td>158</td>
</tr>
<tr>
<td>5.4</td>
<td>On-Site Control Centre Process</td>
<td>160</td>
</tr>
<tr>
<td>5.5</td>
<td>Report Transmission Process</td>
<td>161</td>
</tr>
<tr>
<td>Symbol</td>
<td>Abbreviation</td>
<td>Definition</td>
</tr>
<tr>
<td>--------</td>
<td>---------------------------------------</td>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>ADC</td>
<td>Automatic Data Collection</td>
<td></td>
</tr>
<tr>
<td>AutoCAD</td>
<td>Automated Computer Aided Design</td>
<td></td>
</tr>
<tr>
<td>Auto-ID</td>
<td>Automatic Identification</td>
<td></td>
</tr>
<tr>
<td>BIM</td>
<td>Building Information Modelling</td>
<td></td>
</tr>
<tr>
<td>BQ</td>
<td>Bill of Quantities</td>
<td></td>
</tr>
<tr>
<td>C-aIS</td>
<td>Context-aware Information System</td>
<td></td>
</tr>
<tr>
<td>CCTV</td>
<td>Closed-Circuit Television Camera</td>
<td></td>
</tr>
<tr>
<td>CIDB</td>
<td>Construction Industry Development Board</td>
<td></td>
</tr>
<tr>
<td>DO</td>
<td>Delivery Order</td>
<td></td>
</tr>
<tr>
<td>E-mail</td>
<td>Electronic Mail</td>
<td></td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
<td></td>
</tr>
<tr>
<td>GHz</td>
<td>Giga Heartz</td>
<td></td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
<td></td>
</tr>
<tr>
<td>GPRS</td>
<td>General Packet Radio System</td>
<td></td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communications</td>
<td></td>
</tr>
<tr>
<td>HQ</td>
<td>Head Quarter</td>
<td></td>
</tr>
<tr>
<td>IBS</td>
<td>Industrialised Building System</td>
<td></td>
</tr>
<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
<td></td>
</tr>
<tr>
<td>ILM</td>
<td>Information Lifecycle Management</td>
<td></td>
</tr>
<tr>
<td>ISO</td>
<td>International Organisation for Standardisation</td>
<td></td>
</tr>
<tr>
<td>JIT</td>
<td>Just-In-Time</td>
<td></td>
</tr>
<tr>
<td>kb</td>
<td>kilo byte</td>
<td></td>
</tr>
<tr>
<td>kHz</td>
<td>kilo Heartz</td>
<td></td>
</tr>
<tr>
<td>LADAR</td>
<td>Laser Detection and Ranging</td>
<td></td>
</tr>
<tr>
<td>LAN</td>
<td>Local Area Network</td>
<td></td>
</tr>
<tr>
<td>m</td>
<td>metre</td>
<td></td>
</tr>
<tr>
<td>MHz</td>
<td>Mega Heartz</td>
<td></td>
</tr>
<tr>
<td>MRO</td>
<td>Materials Requisition Order</td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>Materials Storage</td>
<td></td>
</tr>
<tr>
<td>MU</td>
<td>Materials Use</td>
<td></td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operation and Maintenance</td>
<td></td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
<td></td>
</tr>
<tr>
<td>PO</td>
<td>Purchasing Order</td>
<td></td>
</tr>
<tr>
<td>QS</td>
<td>Quantity Surveyor</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>Radio Frequency</td>
<td></td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
<td></td>
</tr>
<tr>
<td>RFID-CMM</td>
<td>RFID-Facilitated Construction Materials Management</td>
<td></td>
</tr>
<tr>
<td>UHF</td>
<td>Ultra High Frequency</td>
<td></td>
</tr>
<tr>
<td>UWB</td>
<td>Ultra-Wide Bands</td>
<td></td>
</tr>
</tbody>
</table>
## LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sample of Interview Questions</td>
<td>182</td>
</tr>
<tr>
<td>B</td>
<td>Sample of Interview Transcript</td>
<td>187</td>
</tr>
<tr>
<td>C</td>
<td>List of Publications</td>
<td>195</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

This chapter presents the context of the research study. Firstly, it starts with brief introduction to the research background and problem statement that brings to the research interest in this study area. Secondly, this chapter states the aim and objectives of the research and the methodology adopted in order to achieve the research objectives. Finally, the chapter present the structure of the thesis.

1.1 Research Background

The demand for construction development is increasing from day to day parallel with increasing in the growth of population. A lot of development has been carried out which comprise of the housing development, infrastructure, industry, institutions, health care and others to fulfil the demand. In project development, materials are among the important elements to be taken into consideration as they are the building blocks that make up a project meanwhile material also constitute large amount of the project costs (Lu et al., 2011). Previous research identified that material cost comprise of 50-60% from the total project costs (Nasir, 2008; El-Ghazali et al., 2011). Therefore, inventory which is part of materials also contribute significant amount to the above percentage.

Inventory in general could be defined as the company’s raw materials, work in process, supplies used in operations and finished goods which were used to ensure smooth running of the business (Muller, 2011; Sahari et al., 2012). However, in construction settings; inventory was referred as materials or components on hand; which was kept by contractors for the smooth functioning of construction processes. Inventory is also known as the stock of materials or components kept at the storage
for future use in construction process. Adequate amount of inventory is crucial to ensure the smoothness of construction processes and to maintain a healthy cash flow for contractors (Lu et al., 2011). However, inadequate amount of inventory results in job stoppage due to materials required for conducting construction works could not be specified at time they are needed.

The management of inventory in construction projects is important where significant amount of money was invested in every single activity. It involves the management of materials or components as they were unloaded to the site storage upon arrival at the project site. Several processes which considered important in inventory management are materials planning, purchasing, materials delivery, materials storage, and materials issue (Waters, 2003). Despite great demand for managing inventory, however; there are several problems which bound existing inventory management practices in construction projects. Those problems are: materials shortage (Ali et al., 2010), over ordering and double handling of inventory, missing materials; unavailability of storage space (Donyavi & Flanagan, 2009), and incomplete and lack of up-to-date information regarding on-site stock (Navon & Berkovich, 2006).

As inventory management has increase in importance, materials tracking for inventory management also have received great attention. Material tracking for inventory management process has become everyone’s concern as construction materials usually come in bulk without proper identification and difficult to be traced. Hence, material’s tracking is important as it could ensure that materials are available at the right time, in the right place and at the right quantity at time are needed to carry out construction work (Song, 2005). However, in construction projects; the tracking of inventory along the supply chain and tracking their locations at jobsites are among important problems related to construction materials (Song, 2005; Navon & Berkovich, 2006; Nasir, 2008). Thus, this research focuses on material tracking practices for inventory management process in construction projects particularly at the storage area.
1.2 Problem Statement

Existing material tracking practices for inventory management in construction projects has several limitations. Material tracking practices relies on manual method of collecting and recording data related to tracking activities which is labour intensive (Ergen & Akinci, 2007). Sardroud et al. (2010) asserts that the data collected using manual method could be questioned as it depends on workers skill and level of productivity at time the data is taken during materials tracking. In addition, received materials is often improperly recorded or not recorded at all (Ala-Risku et al., 2010).

Navon and Berkovich (2006) has highlighted several limitations of manual material tracking which are labour intensive, inaccurate and subjected to error-prone which further leads to waste and surplus of materials, schedule delays, decrease in productivity, and lack of up-to-date information regarding the status of materials. Sardroud et al., (2010) also agreed that manual method of material tracking are labour intensive and data collected is unreliable as they depend on workers motivations and skills to track the materials during its arrival and at the storage area.

Moreover, the data collected through manual materials tracking are usually kept and transferred in paper-based format which is difficult to be traced and accessed in future. Hence, some information is being unavailable to the parties who need access to them in a timely manner for decision making process (Sardroud et al., 2010). Demiralp et al. (2012) also stated that manual material tracking practices are time consuming, results in late deliveries, lead to mislocated components and incorrect installations. Meanwhile, Grau et al. (2009) addressed several limitations of material tracking in which it has raised difficulties among labour craft in accessing the required material and components at time of materials consumption. Thus, this provides less assurance for materials future identification.

Research conducted based on Malaysian construction projects have found that construction projects suffered from several inventory management problems such as improper planning and shortage of materials (Sambasivan & Yau, 2007). Ali et al. (2010) also found that material shortage is the inventory management related problems that contribute to delay among construction projects in the Klang Valley, Malaysia. Hence, Ibrahim et al. (2010) added that surplus of materials are among factors that contribute to project delay in Malaysian construction projects. The
inventory management related problems that occur in Malaysian construction projects is contributed by the inexistence of appropriate material tracking practices for inventory management process.

However, the advancement in Information and Communication Technology (ICT) provided an opportunity to improve material tracking practices for inventory management process in construction projects. Previous researchers have introduced technology to overcome the drawbacks of existing material tracking practices (Chen & Li, 2006; Moselhi & El-Omari, 2006; Grau et al., 2009; Sardroud et al., 2010). Technologies such as bar-coding, Radio Frequency Identification (RFID), Global Positioning System (GPS), wireless technology and others has ability to facilitate materials tracking for the purpose of inventory management and materials control. Regarding to Moselhi and El-Omari (2006), bar-coding, RFID and other wireless technology could improve the speed and accuracy of data acquisition in construction projects in a cost effective manner.

Bar-coding technology has been used in materials tracking to provide instant and up-to-date information on quantities of materials and equipments exchanged between the store keepers and the working groups (Chen & Li, 2006). In contrast, RFID technology could provide unique identification and real-time information (Sarac et al., 2010) in construction projects. As ICT implementation offers great advantage in terms of material tracking especially in the construction industry abroad, therefore; ICT is expected to be adopted in Malaysian construction projects to overcome inventory management related problems especially in the area of materials tracking.

However, a framework is needed for successful adoption of technology for materials tracking in construction projects. Although previous researchers such as Gajamani and Varghese (2007), Kasim (2008), Sardroud et al. (2010), Ren et al. (2011), Sardroud (2012) and Lee et al. (2013) have developed several materials tracking framework, however; this framework does not focused on materials tracking for inventory management at the storage area. Yet; there is still lack of example of material tracking framework for inventory management processes in construction projects particularly focusing at the storage area. Therefore, this research is intended to develop an on-site material tracking framework for inventory management process which act as guidance for contractors in order to successfully adopting technology for materials tracking in construction projects.
1.3 Research Questions

Based on the problem statement, several research questions have been posed which comprise:

(i) What is the potential implementation of RFID technology for material tracking in Malaysian construction projects?
(ii) How does material tracking for inventory management process is practised among Malaysian construction projects?
(iii) How to improve the on-site material tracking for inventory management process in Malaysian construction projects?

1.4 Aim and Objectives

This study aims to improve on-site materials tracking for inventory management process in construction projects particularly at the storage area. Towards reaching the aim of the research, the following objectives have been formulated as reflected in Table 1.1.

Table 1.1: Research Objectives and Chapter Outcome

<table>
<thead>
<tr>
<th>No.</th>
<th>Objective</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>To study potential implementation of RFID technology for materials tracking in Malaysian construction projects</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>2.</td>
<td>To investigate existing material tracking practices for inventory management process in Malaysian construction projects.</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>3.</td>
<td>To develop an on-site materials tracking framework for improving inventory management processes in Malaysian construction projects.</td>
<td>Chapter 5</td>
</tr>
</tbody>
</table>

1.5 Scope of the Research

The research focuses on developing an on-site materials tracking framework for inventory management process in construction projects particularly at the site storage area. The target population for this research is main contractors registered with Construction Industry Development Board (CIDB) Grade 7 (G7) or registered with Contractor Service Centre (PKK) Grade A. G7 contractors are selected as they has unlimited tendering capacity (Construction Industry Development Board, 2013)
therefore has experience in developing multi-million construction projects and has high capability for using technology in their projects. However, the samples of this research is only two hundred and thirty six (236) which consist of main contractors specialised in building construction which located in three different states namely; Johor, Selangor and Negeri Sembilan (CIDB, 2012). Those states are selected since they are moving forward among other states in terms of having progressively expanding in the volume of new construction development (Construction Industry Development Board, 2012). Case study research was adopted as a research strategy while semi-structured interview was used to gather data about the research. Respondent of the research are related personnel having experience or involved directly in inventory management and overall site management such as the project manager, the site engineer and the site supervisor. The data obtained from semi-structured interviews was analysed using matrix table and thus, presented as ‘within case’ and ‘cross-case’ reports.

1.6 Research Methodology

In achieving the aim and the research objectives, several research methods were adopted. This includes literature review, case studies and development of the on-site materials tracking framework for inventory management. Figure 1.1 shows the method adopted for this research with the respective output from each activity. Discussions in detail on the methodology adopted throughout the research were presented in Chapter 3.

(a) Literature Review

Literature related to the research was achieved from sources such as books, journal articles, proceeding papers and online data sources such as webpage of firms, governments, semi-government organizations and catalogues. Literature review in this research starts with reviewing existing literature on RFID technology in material tracking for inventory management in construction projects. This takes into account the implementation of RFID for materials tracking either locally or internationally. Upon reviewing the literature, the research problems were established concurrently.
The outputs generated from the review are the research contexts in RFID technology implementation for materials tracking and the successful RFID implementation in construction projects.

(b) Case Studies: Interviews

The case study approach was undertaken to gain primary data for this research. The case or unit of analysis involved ten construction projects in order to investigate existing material tracking for inventory management process within each case. Construction projects participate in the research are selected due to several criteria. Such criteria include the projects must be constructed by main contractors registered
with Construction Industry Development Board (CIDB) Grade 7 (G7) or registered with Contractor Service Centre (PKK) Grade A.

The case studies involved face-to-face semi-structured interviews in which the respondents are selected based on purposive sampling. According to Oliver (2006), purposive sampling is a type of sampling in which the decisions regarding the individuals to be participated in the research are determined by the researcher based upon variety of criteria which required by him or her. Hence, respondents for this research are selected based on their experience and involvement in inventory management and the overall site management such as the project manager, the site engineer or the site supervisor.

A list of predetermined and standardised questions was also prepared for the interview which acts as the interview guideline. This is important as according to Cavana et al. (2001), the semi-structured interview need to be carefully ordered and worded in a detailed interview schedule. Finding from case studies reveal the inventory management processes undertaken in each project, key problems related to materials tracking, implementation of technology for materials tracking, several approaches to improve materials tracking and the integration of inventory management and resource modelling.

The identification of material tracking problems from each case study enables the researcher to propose the adoption of ICT, particularly RFID technology to overcome material tracking related problems within construction projects. However, the decision to adopt RFID technology was made based on results from literature review which reveals the advantages of RFID technology for materials tracking. RFID implementation enables the material to be scanned automatically (Ozumba & Shakantu, 2008; Sardroud, 2012), reduce labour hours in scanning materials, could track work-in progress, improves antitheft protection and better inventory management (Mehrjerdi, 2011).

(c) Framework Development

The development of the on-site materials tracking framework for inventory management process carried out from both literature review and case studies findings. It starts with the identification of material tracking components and its
element obtained from previous literature. The on-site materials tracking framework was developed based on the suitability of each component and elements with the actual material tracking practices for inventory management process carried out on-site. Several questions were designed for the interviews to enable the researcher to identify suitable components and important elements for the framework. The developed framework is important to successfully adopting technology in materials tracking for inventory management process in Malaysian construction projects.

1.7 Significance of the Research

This research is expected to contribute to the body of knowledge and study by:

- identifying the current status of RFID implementation for material tracking in Malaysian construction projects,
- exploring inventory management processes and identifying existing problems related to material tracking in Malaysian construction projects, and
- propose new on-site material tracking framework for inventory management by improving the existing framework.

1.8 Structure of the Thesis

The thesis is structured into six chapters respectively. The content of each chapter are as follows:

Chapter 1 briefly introduces the content of the research. It explains the research background, problems that bring into the research initiative, the aim and objectives; and the methodology used in the research.

Chapter 2 reviews the literature related to the research. It focuses on the material tracking practices for inventory management processes in construction sites. The chapter also review the current ICT implementation to facilitate materials tracking in construction projects.
Chapter 3 reviews the overall methodology in business research and the method adopted to carry out this research project. This chapter also provide justification for the adoption of the specific research method.

Chapter 4 explains the findings from the case studies undertaken for the research. The findings were used to reveal the material tracking problems and the use of ICT to improve current material tracking practices in construction projects.

Chapter 5 focuses on development of on-site materials tracking framework. In this chapter, each component of the on-site materials tracking framework were discussed in details and their integration with RFID were discussed.

Chapter 6 presents the summary and conclusions for the thesis. This chapter discusses the research findings, conclusions, contributions and several limitations of the research. In addition, this chapter also provides some recommendations for future research.

1.9 Summary

This chapter outlined several problems in materials tracking for inventory management and justify the importance to conduct the research. Several problems have been identified regarding materials tracking for the inventory management in construction projects. The manual method of material tracking use in construction projects are labour intensive and rely greatly on paper-based reports which is difficult in term of traceability. This chapter also outlined the aim and the research objectives; together with the research methodology and structure of the thesis. The next chapter explained the literature undertaken for this research.
CHAPTER 2

MATERIALS TRACKING FOR INVENTORY
MANAGEMENT PROCESS

2.1 Introduction

This chapter reviews inventory management and material tracking technologies for inventory management process in construction projects. Firstly, it describes the inventory management as a whole which consist of definition, the process, the importance and problems in inventory management; and the application of information and communication technology (ICT) in managing inventory. Secondly, it explains the need for material tracking and existing material tracking practices in construction projects. Thirdly, it describes the material tracking technology and its benefits for material tracking. Finally, the chapter demonstrated the use of RFID for material tracking and issues of deployment.

2.2 Inventory

Adequate amount or level of inventory is important in every business to ensure business processes for example the manufacturing of goods could be carried out successfully. Research conducted by Lu et al. (2011) has found that, materials (including inventory) constitute a great portion from the total costs in construction projects. However, in order to have better understanding on inventory; it is important to go through their definitions and why inventory is so important.
2.2.1 Definitions of Inventory

In general, inventory could be defined as the company’s raw materials; work in process, supplies used in operations, and finished goods (Muller, 2011; Sahari et al., 2012). Inventory is the amount of raw materials, fuels, lubricants, spare parts and semi-processed material to be stocked for the smooth functioning of the plant (Chitale & Gupta, 2006). According to Maré (2006), inventory were use to mean several different things, such as:

- the company’s or firms raw materials;
- work in process;
- components/sub-assemblies;
- finished goods;
- maintenance, repair and operational supplies; and
- transportation inventory (movement inventory).

In construction projects, inventory refers to materials or components on hand; which is kept by construction firms or projects as stock for the smooth functioning of construction process. In addition, inventory in construction also could be referred to as the amount of materials or components on the storage area. Regardless their definitions, it is important for businesses to manage inventory for their survival. Adequate amount of inventory helps company to fulfil customer need and demands, and vice versa; the company may incurred loss in profit margins. Therefore, there is a need for effective and efficient inventory management processes in construction projects. As according to Navon and Berkovich (2005), the main benefits arises from efficient materials management or inventory management are increased productivity, avoidance of delays, reduction of labour working hours and reduction in materials cost. Thus, effective and efficient inventory management processes is needed to help improve overall inventory management in construction projects.

2.2.2 The Importance of Inventory

Why businesses need inventory or why inventory is so important? Why do businesses keep inventory in their organisations? As in just-in-time (JIT)
manufacturing concept, keeping a stock or inventory is considered as a waste. However, according to Muller (2011) there are several reasons for holding inventory in organisations. Such reasons are:

- **Predictability**
  In order to engage in capacity planning and production scheduling, organisations need to control the inventory quantity (raw materials, parts, and sub-assemblies) they had processed at a given time. This is important as inventory will act as a buffer as what you need from what you want.

- **Fluctuations in demand**
  Inventory on hand acts as a protection against undesirable market conditions. Inventory of finished goods is important in protecting companies from an increase in customers demand.

- **Unreliability of supply**
  Inventory will provide organisations with a protection from unreliable suppliers and in scarce conditions where it is difficult to ensure a steady supply of materials and items.

- **Price protection**
  Buying and keeping large quantities of inventory at appropriate time helps avoid the impact of cost inflation.

- **Quantity discounts**
  Buying large amount of items such as buying in bulk is much susceptible to quantity discounts as compared to buying in smaller quantities.

- **Lower ordering costs**
  Buying large quantity of several items, but in less frequent will result in lower ordering costs. This are differed with buying a small quantities of an item, but in much frequent.

Keeping or having adequate level of inventory is important for every business. This is due to inventory carries large amount of hidden cost (Sahari et al., 2012) such as the cost of equipment to handle them, warehouse, deterioration or damage if any, and other related costs. In construction projects, adequate amount of inventory (materials, equipments, tools, etc.) is important to ensure that all construction works could be carried out according to schedule. Apart from adequate
amount of inventory, the management of inventory itself is an important concern in construction projects. Therefore, current material tracking practices used in managing inventory in construction projects has successfully captured a great concern among contractors and clients.

2.3 Inventory Management Processes

In general, inventory management is specifically responsible for the management of inventory as they arrive at the construction site, their storage and the disposal of inventory wastes. According to Waters (2003), inventory management is so entwined with activities in logistics which responsible for all aspects of the movement and storage of materials in a supply chain. Inventory management in construction projects consists of five main processes. Those processes were discussed in the following sub-sections.

2.3.1 Planning

Planning is the initial process and could be considered as the most important process in inventory management. Materials planning involve determining the need for materials to carry out production process and other related works. During planning, if material is estimated wrongly; the stock level will become too high and generate other hidden costs. However if the stock level is too low, it may lead to another problems which related to the distribution (Heck, 2009).

In construction, appropriate planning for materials is important and must be done concurrently with engineering, construction and other project plans (Kasim, 2011). The author also identifies the process in planning which includes quantifying, ordering and scheduling. Materials planning in construction involve activities such as determine the type of materials which to be used in construction works, its quantities, and specifications in order to carry out construction works. Material planning in construction projects has significant contribution in increasing work productivity, increase profit and facilitating the timely completion of construction projects.
2.3.2 Purchasing

Procurement or purchasing could be defined as the purchase of materials and services from other organisations in order to support the firm’s operations (Kasim, 2011). The person in charge for procuring materials or the purchasing department in case of large construction firms need to ensure that the right materials in the right quantities are purchased from suppliers or manufacturers. Such person also needs to verify the release dates at which the material is needed and to clearly specify those delivery dates and the location of delivery to the supplier (Al-Shorafa, 2009).

The purchasing and planning process are interrelated. This is due to, before the buying process; the advance planning is required in order to determine the amount of inventory needed for each time period (Hedrick et al., 2013). After the need for materials was identified, decisions regarding the buying needs need to be done which include whether to buy or not and in what quantities. Before the purchasing order were issued to suppliers or manufacturers, it is important to highlight the exact time in which the materials are going to be used and for which activities. This is important to ensure materials availability to carry out construction works.

2.3.3 Materials Delivery

Usually, materials are delivered to the project sites during the construction phase. However, in several instances the delivery of materials to the jobsites may not be feasible due to storage or access limitations (Al-Shorafa, 2009). This means that construction materials cannot be delivered to the project sites due to unavailability of the site storage space. Sometimes, the locations of the project site from the main road or main area contribute difficulties for manufacturers and suppliers to delivered or shipped construction materials.

In such cases, construction materials were delivered or shipped to other locations such as the contractor’s warehouse, a prefabrication shop or the subcontractor storage area (Al-Shorafa, 2009). In situations where construction materials are delivered successfully to the site, workers usually the site supervisor’s need to checked the delivered materials upon their receipt. The site supervisor need
to check the delivered material in terms of its quantity and specifications and compared the information with the purchase order (Heck, 2009). At this time, the materials which required for further storage are segregated or separated from materials which required to be used for immediate construction activities.

2.3.4 Storage

Materials were added to the stock after checking during materials delivery. The amount or quantities of materials added to the stock need to be recorded in the store database (whether using paper-based or registered in the system) for further use by the store keeper in managing the site storage area (Heck, 2009). Adequate information on materials identification at the storage area is important to enable workers to easily retrieve the materials. In addition, proper management at the site storage area is also important to ensure that materials are available at time they are needed, thus; avoiding problems related to the unavailability or lack of materials such as double handling and inadequate site storage.

2.3.5 Materials Issue

According to Heck (2009), materials or goods were issued for two reasons; each of which would depend on its environment. In a warehouse, items or goods were issued to fulfil an order placed by clients. However, in a production environment; items are retrieved from stock as they are required for production of goods (Heck, 2009). Construction materials were issued from the site storage or the unloading area; to the workers to carry out construction works. Materials which were taken out from the storage were recorded in the store database. However, materials that were taken directly from the unloading area upon their received need to be deducted directly from the inventory lists.

Materials issuance needs high degree of supervision from the person in charge of the site storage area. If it was undertaken without proper supervision, materials flow may be not recorded at all; or even worse the materials were taken out in excessive amount which contribute to wastage. Hence, materials issuance is
important to control the flow of materials in and out from the site storage and in construction projects.

### 2.4 Inventory Management in Construction Projects

In traditional settings, inventories of raw materials, work-in-process and finished goods were kept as a buffer against the possibility of running out of needed items (Sahari et al., 2012). However, large inventories consume valuable resources and generate hidden costs. Adequate inventory level is important for businesses to keep up competing in the market conditions while operating the business smoothly. On the other hand, high inventory level could burden the companies as inventories carried out hidden costs.

Inventory management is one of the most important operations management responsibilities as inventory involves great deal of capital and the delivery of goods from manufacturers to the suppliers and customers (Chitale & Gupta, 2006). Therefore, the management of inventory is important as it has great impact on the overall business functions. In construction project, materials and equipments may constitute more than 60% of the total project cost (Donyavi & Flanagan, 2009; Patel & Vyas, 2011), hence; make the management of materials and inventory as crucial.

In addition, Tersine (1994) asserts that the management of inventory is a common problem to all organisations in any economic sector. Like other sectors such as manufacturing, automotive, electronics and others; construction industry also suffered from poor inventory management especially during construction phase. In Malaysia, inventory management related factors such as materials shortage and equipment and tools shortages are among factors that contribute delay to the construction projects (Sambasivan & Yau, 2007; Alaghbari et al., 2007; Ali et al., 2010). Therefore, the project management team need to take superior attention on inventory management in construction projects to ensure materials availability during conducting the construction works.
Table 2.1: Summary of Inventory Management in Construction Projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Year</th>
<th>Key Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Materials</td>
</tr>
<tr>
<td>1</td>
<td>Tersine</td>
<td>1994</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>Chitale &amp; Gupta</td>
<td>2006</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>Alaghbari et al.</td>
<td>2007</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Sambasivan &amp; Yau</td>
<td>2007</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>Donyavi et al.</td>
<td>2009</td>
<td>✓</td>
</tr>
<tr>
<td>6</td>
<td>Ali et al.</td>
<td>2010</td>
<td>✓</td>
</tr>
<tr>
<td>7</td>
<td>Patel &amp; Vyas</td>
<td>2011</td>
<td>✓</td>
</tr>
<tr>
<td>8</td>
<td>Sahari et al.</td>
<td>2012</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 2.1 summarised several researches that has been carried out regarding the inventory management in construction projects. From the table, it is clear that the inventory management in construction projects has received a great concern among researchers. Therefore, inventory in construction projects need to be managed properly or vice versa it can causes schedule and project delays which in turn contribute to the project failure. The next section discusses on the inventory management problems in construction sites.

2.5 Inventory Management Problems

Existing inventory management in construction projects are susceptible to various problems. Table 2.2 has summarises several inventory management problems which occur in construction projects abroad and in Malaysia. From the table, Donyavi and Flanagan (2009) have found out common problems related to inventory management in construction projects. In their study; failure to order on time, wrong delivery time, over ordering, wrong materials or error in direction requiring rework, double handling and theft of materials are common inventory management problems in construction sites. Inventory management in construction projects also suffered from inadequate site storage space (Kasim, 2010). Due to inadequate site storage space, delivered materials were leave scattered everywhere around the construction area, thus; increase difficulties for materials traceability.

In another research, Sardroud (2012) has identified several major problems related to inventory management in construction projects. Those problems are: materials required but not purchased, wrong time for delivery of materials, lack of
complete and up-to-date information regarding the site stocks; missing or surplus of materials; inadequate site storage space; and waste of working hours searching for materials and in tracking them. Similar to the other inventory management problems, these problems also result in the decrease of labour productivity, schedule delays and increase the project costs.

Table 2.2: Inventory Management Problems in Construction Projects

<table>
<thead>
<tr>
<th>No.</th>
<th>Author</th>
<th>Year</th>
<th>Inventory Management Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Construction Projects Overseas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Jang &amp; Skibniewski</td>
<td>2008</td>
<td>- Manual material tracking in which it is labour intensive, inaccurate &amp; subjected to error, wastage, surplus materials, schedule delay, decrease in productivity and lack of timely information regarding materials.</td>
</tr>
</tbody>
</table>
| 2.  | Donyavi & Flanagan    | 2009 | - Failure to order materials on time  
- Wrong delivery time  
- Over ordering  
- Wrong materials or error in directions requiring rework  
- Double handling  
- Theft |
| 3.  | Kasim                 | 2010 | - Inadequate site storage space                                                                                                                                  |
| 4.  | El-Ghazali et al.     | 2011 | - Manual material tracking in which it is labour intensive, inaccurate & subjected to error, wastage, surplus materials, schedule delay, decrease in productivity and lack of timely information regarding materials. |
| 5.  | Sardroud              | 2012 | - Required materials are not purchased  
- Wrong delivery time  
- Late of timely information regarding on-site stock  
- Materials missing and surplus of materials  
- Inadequate storage space  
- Waste of man-hours searching for materials and in tracking them |
|     | **Construction Projects in Malaysia** |      |                                                                                                                                                                |
| 1.  | Sambasivan & Yau      | 2007 | - Shortage of materials  
- Equipment and tool shortage                                                                                                                                 |
| 2.  | Alaghbari et al.      | 2007 | - Shortage of materials  
- Equipment and tool shortage                                                                                                                                 |
| 3.  | Ali et al.            | 2010 | - Shortage of materials  
- Equipment and tool shortage                                                                                                                                 |
| 4.  | Ibrahim               | 2010 | - Surplus of materials  
- Late delivery of materials  
- Improper planning                                                                                                                                          |
| 5.  | Hamzah et al.         | 2012 | - Shortage of materials  
- Equipment and tool shortage                                                                                                                                 |

In addition, inventory management in construction also suffers from traditional-manual material tracking practices (Jang & Skibniewski, 2008; El-Ghazali et al., 2011). According to Sardroud et al. (2010), manual material tracking relies on workers efficiency to track and identify materials in construction jobsites. This method is labour intensive, inaccurate and subjected to error-prone, which further leads to waste and surplus of materials, schedule delays, decrease in productivity,
and lack of up-to-date information regarding the status of materials. Data collected using manual method is also unreliable as it depends on workers initiative to collect data regarding materials.

In Malaysia, shortage of materials and equipment and tool shortages are among the common problems related to inventory management in construction projects (Sambasivan & Yau, 2007; Alaghbari et al., 2007; Ali et al., 2010; Hamzah et al., 2012) besides other factors such as surplus of materials (Ibrahim, 2010), late delivery of materials and improper planning. On the other hand, shortage of materials is also among the major factors that contribute delays of construction projects in the Klang Valley, Malaysia (Ali et al., 2010). However, little research has been carried out regarding the problems faced by Malaysian construction industry related to inventory management in construction projects (Ibrahim, 2010).

In case of material shortage, materials required to carry out specified jobs are unavailable when needed, thus; result in delay of construction works, wasting of labour hours and equipments and increase the total project cost (Ali et al., 2010). From the above study, it is expected that inventory management problems which occur among Malaysian construction projects are contributed by the inexistence of proper material tracking system for the purpose of managing inventory in construction projects. Song (2005) has highlighted the importance of proper material tracking in which it provides timely information on materials availability. Timely information on materials is important for the site manager to make proper planning on construction works based on materials availability and to make decision regarding the purchasing of materials. Hence, materials shortage, surplus of materials and other inventory management problems could be avoided.

The above literature revealed several inventory management problems which occur in construction projects including existing problems in Malaysia. Therefore, it could be concluded that effective material tracking practices is required in managing inventory. Fail to manage inventory results in schedule delays, increase labour working hours, decrease productivity and increase the production costs. Hence, this research intended to highlight the importance of material tracking practices for inventory management processes in construction projects.
2.6 Material Tracking for Inventory Management

Material tracking in construction projects is not an easy task (Navon & Berkovich, 2006). This is due to construction projects involve large amount of materials to fulfil the demand of construction activities. Thus, it is important for the project management to be able to trace every construction materials to make sure construction works could be carried out in line with the availability of resources (construction materials).

2.6.1 The Importance of Material Tracking

The term material tracking could be defined as the process of collecting and managing information related to present or real-time location of a products or items (Shamsuzzoha & Helo, 2011). Material tracking in construction project is crucial as materials constitute large portion of the total project costs. According to Green (2005), material tracking in construction projects is important because of several reasons; (i) to know exactly the location of materials, so workers do not have to waste their time searching for materials, (ii) to make sure jobs and orders are not held up because of lack of materials, (iii) to track the quality and cost of each container of material in order to make sure that the correct materials are received according to purchase orders, (iv) to make sure the manufacturers have shipped the right materials to the customer; and (v) the need for traceability.

Material tracking system helps to identify the position of the shipment and informed the customer about the products or items location in well advance. Vice versa, it is impossible to find out delivered items and to track lost or stolen item without material tracking system (Shamsuzzoha & Helo, 2011). In another research, Song (2005) stated that materials’ tracking in construction projects is important because of two reasons. Firstly, materials tracking could provide timely information on materials availability to enhance crew-level work planning and improve labour productivity. Secondly, materials tracking enable real-time on-site measurement of project performance indicators that provide the project management with feedback information for project control. In construction projects, both timely information on
material and real-time on-site measurement of project performance is important for the project management to make decision regarding the project.

Construction environment also demanding high materials traceability where materials need to be at predetermined locations at time they are needed (Song, 2005). This is important primarily to facilitate materials consumption during construction works. At the storage area, material tracking were used to know the specific quantity of every item within the storage. This is important in order to have correct information regarding materials in stock while at the same time making new purchase order if the inventory level is low. Therefore, materials tracking play an important role for the purpose of inventory management processes in construction projects. Fail to track materials means failed to manage inventory which could affect on the overall project performance.

2.6.2 Current Approaches of Materials Tracking

According to Sardroud et al. (2010), current material tracking practices in construction projects rely greatly on manual data collection process. Manual data collection is inefficient and ineffective as the data collected is not reliable and accurate. In construction project, accurate and timely information is primary concern among various parties in the project in order to increase the project control. However, Grau et al. (2009) has demonstrated current method of material tracking which were used to tracked pre-fabricated components such as structural steel and pipe spools in construction jobsites.

In their research, structural steel and pipe spools were first unloaded and stored in the lay down yard upon their arrival at the construction site. Then, the delivery information (i.e. delivery date and truck number) was hand-marked to the components. The piece mark of each received components and their grid location in lay down yard was manually recorded by workers in paper-based format. Later, this information was manually keyed into an electronic materials management system for future use. At the lay down yard, there are possibilities where those components may be moved to different grids at different times. To have updated inventory information, workers need to records the new grid location of the components in every possible movement. Therefore, manual material tracking is very labour
intensive and involve excessive paper-based as workers are required to record the location of the components in every possible movement before installation process.

Not much research has been conducted regarding material tracking in Malaysian construction projects. Kasim et al. (2013) found that existing material tracking practices among four construction projects in Malaysia was undertaken manually which has several drawback. Liwan et al. (2013) also revealed that Malaysian contractors rely on manual material tracking practices which is susceptible to several drawbacks. In addition, the CIDB master plan for occupational safety and health 2004 (CIDB Master Plan OSHA 2004) also highlighted that one of the problems facing by the Malaysian construction industry is low productivity which contribute by the low technology usage. It also show that Malaysian construction industry is lag far behind other industries in embracing technology and therefore; the overall project management were carried out manually including materials tracking.

Several case studies have been conducted to explore material tracking practices in Malaysian construction projects. It is found that each material was calculated manually one-by-one by the personnel in charge upon its arrival at the project site with referred to the Delivery Order (DO) (Liwan et al., 2013). Every time materials were delivered to the construction site, the site supervisor need to manually check and tracked the materials to ensure it is according to the DO (Kasim et al., 2013). This is to ensure that the types, quantity, quality and specifications of materials arrived at the site is according to the DO. However, Malaysian construction projects also suffered from manual material tracking related problems. Kasim et al. (2013) reported that manual material tracking practices are labour intensive, lack of up-to-date information regarding materials and involved excessive paper-based recording and reporting. In addition, manual method of materials tracking also involved excessive paper-based recording, lack of timely information on materials, inadequate storage space, theft and others (Liwan et al., 2013).

Sardroud et al. (2010) has stated several drawbacks of manual material tracking in which it is labour intensive, inefficient and data collected using these methods are unreliable as they depend on workers motivations and skills to collect data on materials. In addition, data collected through manual method are usually kept and transferred in paper-based format, which is difficult to be reached in term of its accessibility and traceability. Current material tracking practices also time
consuming, results in late deliveries, lead to mislocated components and incorrect installations (Demiralp et al., 2012). Although current material tracking practices has many drawbacks, however; the advancement in ICT could be manipulated to improve current practices. Several technologies could be adopted to assist and improve material tracking in construction projects. Brief explanations on those technologies were explained on the next section.

2.6.3 Materials Tracking Technology

The implementation of technology in everyday’s life has ability to assist human works while at the same time improving their life quality. Hence, the implementation of technology particularly for material tracking in construction projects is expected to facilitate and improve existing material tracking practices. From previous research, there are several technologies which were used for material tracking. Explanations on each technology were made as follows.

2.6.3.1 Bar-coding

Bar-coding have been successfully positioned itself against other identification systems over the past two decades. Bar-coding is a binary code comprising of bars and gaps arranged together in parallel configuration. The bars and gaps were arranged according to a predetermined pattern and represent data elements that refer to an associated symbol (Finkenzeller, 2010). Figure 2.1 depicts the example of bar-coding label which available in the market.

Figure 2.1: Bar-coding Label
REFERENCES


