

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

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PERPUSTAKAAN

ABSTRACT

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

Pengurusan inventori penting terutamanya di dalam projek pembinaan kerana bahan dan komponen pembinaan menyumbang sebanyak 50-60% daripada kos keseluruhan projek. Pengurusan inventori telah menarik perhatian pelbagai pihak yang terlibat di dalam projek pembinaan begitu juga dengan pengesanan bahan untuk pengurusan inventori. Pengesanan bahan dapat memberikan maklumat terkini mengenai bahan binaan dan membolehkan prestasi projek diukur mengikut keadaan semasa di tapak pembinaan di mana ini adalah penting untuk pengurusan inventori. Walaubagaimanapun, kaedah pengesanan bahan yang digunapakai di dalam projek-projek pembinaan adalah menggunakan kaedah manual di mana ia mempunyai banyak kelemahan. Walaupun penggunaan teknologi amat diperlukan untuk membantu pengesanan bahan binaan, tetapi; kerangka kerja pengesanan bahan untuk tujuan pengurusan inventori di tapak pembinaan masih lagi kurang. Oleh itu, kajian ini bertujuan untuk membangunkan satu kerangka kerja pengesanan bahan untuk membantu memperbaiki proses pengurusan inventori di dalam projek pembinaan di Malaysia. Di dalam kajian ini, potensi penggunaan teknologi RFID untuk pengesanan bahan serta kaedah pengesanan bahan yang digunapakai di dalam projek pembinaan dikenalpasti. Kaedah literatur dan kajian kes digunakan untuk mendapatkan maklumat penyelidikan. Sebanyak sepuluh kajian kes dijalankan untuk mengetahui proses pengurusan inventori dan kaedah pengesanan bahan binaan yang digunakan di dalam projek pembinaan di Malaysia. Analisis data kajian melibatkan analisis kes secara individu dan analisis kes secara bersilang. Dapatan kajian ini disimpulkan dengan membangunkan satu kerangka kerja pengesanan bahan binaan untuk membantu proses pengurusan inventori di mana ianya terdiri daripada tujuh komponen iaitu; proses pengeluaran, penghantaran, penerimaan bahan, penyimpanan bahan, pengeluaran, pusat kawalan (di tapak pembinaan) dan penjaan laporan. Kerangka kerja ini amat berguna bagi kontraktor yang mempunyai keinginan untuk mengaplikasikan teknologi RFID untuk membantu dan mempercepatkan proses pengesanan bahan binaan terutamanya di kawasan stor binaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

ADC	Automatic Data Collection
AutoCAD	Automated Computer Aided Design
Auto-ID	Automatic Identification
BIM	Building Information Modelling
BQ	Bill of Quantities
C-aIS	Context-aware Information System
CCTV	Closed-Circuit Television Camera
CIDB	Construction Industry Development Board
DO	Delivery Order
E-mail	Electronic Mail
GIS	Geographic Information System
GHz	Giga Hertz
GPS	Global Positioning System
GPRS	General Packet Radio System
GSM	Global System for Mobile Communications
HQ	Head Quarter
IBS	Industrialised Building System
ICT	Information and Communication Technology
ILM	Information Lifecycle Management
ISO	International Organisation for Standardisation
JIT	Just-In-Time
kb	kilo byte
kHz	kilo Hertz
LADAR	Laser Detection and Ranging
LAN	Local Area Network
m	metre
MHz	Mega Hertz
MRO	Materials Requisition Order
MS	Materials Storage
MU	Materials Use

O&M	Operation and Maintenance
PDA	Personal Digital Assistant
PO	Purchasing Order
QS	Quantity Surveyor
RF	Radio Frequency
RFID	Radio Frequency Identification
RFID-CMM	RFID-Facilitated Construction Materials Management
UHF	Ultra High Frequency
UWB	Ultra-Wide Bands



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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

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

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.

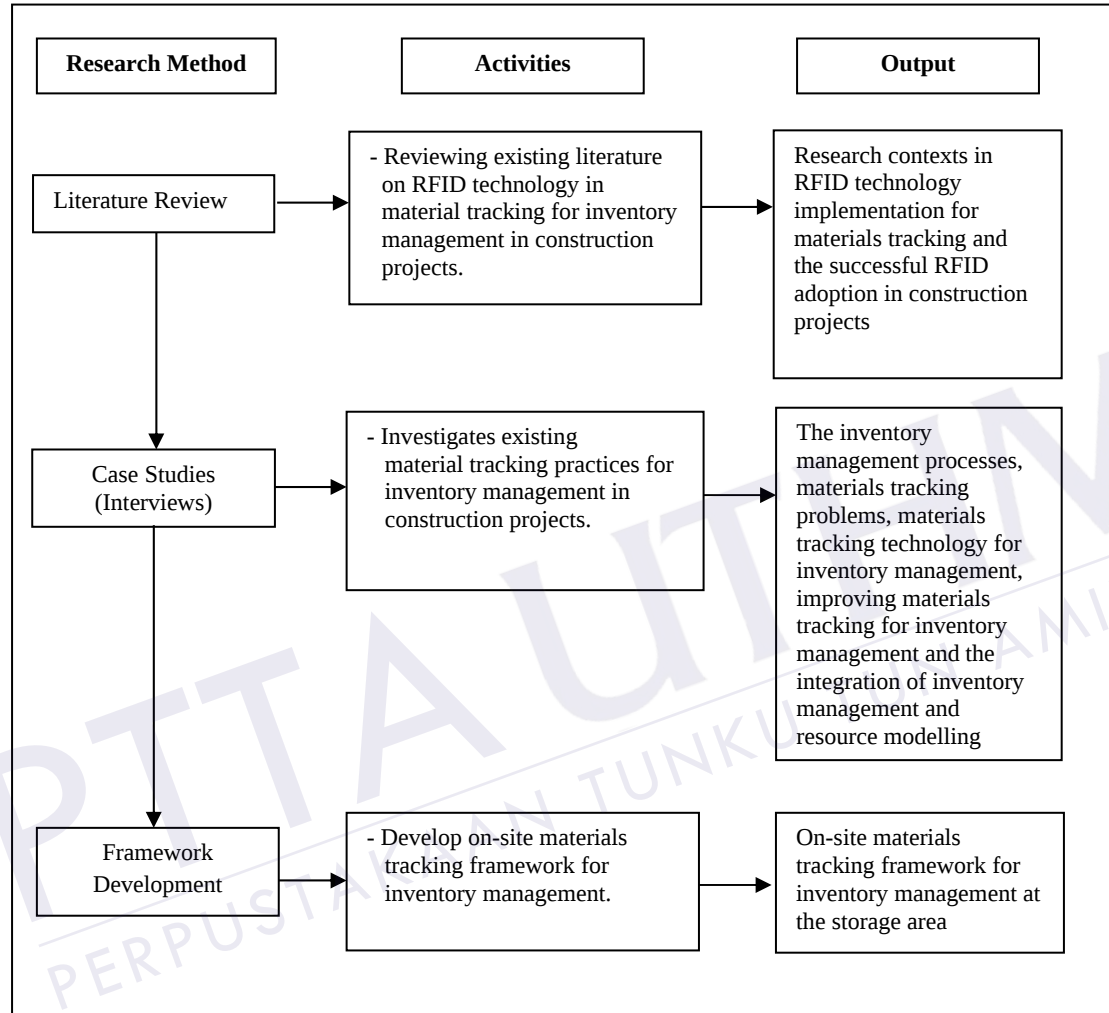


Figure 1.1: The Research Process Flow Chart

(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 (Mehrerjerdi, 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.

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