APPLICATION OF SUPPLY CHAIN OPERATIONS REFERENCE (SCOR) MODEL IN READY MIXED CONCRETE SUPPLY CHAIN: A CASE STUDY

PANHAVUTH LY

A THESIS REPORT SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
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THESIS TITLE	Application of Supply Chain Operations Reference (SCOR) Model in Ready Mixed Concrete Supply Chain: A Case Study
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ABSTRACT

Supply Chain Operations Reference (SCOR) model has been implemented by organizations for their supply chain improvement and performance. SCOR model provides an analytical tool to diagnose organization's supply chains including process and performance. However, to achieve the best of organization directive goals, critical or important strategic performances need to be focused by top management levels. Therefore, this study aims to present the application of SCOR model to map the supply chain process, and to select critical performance metrics in the scope of deliver process. The Analytical Hierarchy Process (AHP) method is used for performance metrics selection. The results of this study are expected to provide useful information for ready mixed concrete industry in process mapping and performance of supply chain operations.

Key Words: SCOR model; Deliver Process; Performance metrics; AHP method; Ready Mixed Concrete

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Panhavuth Ly

TABLE OF CONTENTS

Chapter **Page**

ABSTRACT……………………………………………………………………...I

ACKNOWLEDGEMENT II

TABLE OF CONTENTS..III

LIST OF TABLES...V

LIST OF FIGURES VI

CHAPTER 1 INTRODUCTION 1

1.1 Research Background..1

1.2 Statement of the Problem 2

1.3 Objectives of the Study 2

1.4 Scope of the Study...3

CHAPTER 2 LITERATURE REVIEW 4

2.1 Ready Mixed Concrete Industry..4

2.2 Ready Mixed Concrete Supply Chain Operation Process..................................7

2.3 Ready Mixed Concrete Outbound Logistics Process...8

2.4 SCOR Model 9

2.4.1 SCOR Processes 11

2.4.2 SCOR Deliver Process... 15

2.4.3 SCOR Performance Metrics 16

2.4.4 Environmental SCOR Performance... 20

2.5 AHP Method in SCOR Model 233

CHAPTER 3 RESEARCH METHODOLOGY 255

3.1 Conceptual Framework 255

3.2 Research Design 266

3.3 Method of Data Analysis...277

CHAPTER 4 RESULT AND DISCUSSIONS 31

4.1 Deliver Process modeling with SCOR Framework..31

4.2 Performance Metrics Selection Priority with AHP 366

4.3 Environmental Sustainable SCOR Performance Metrics Selection..................38

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS...........................399

5.1 Conclusions 399

5.2 Limitation of the Study..39

5.3 Recommendations 40

REFERENCES 41

APPENDIX A 433

APPENDIX B 504

APPENDIX C 50

AUTHOR BIOGRAPHY..533

LIST OF TABLES

Table **Page**

Table 2.1 Typical mix design of ready mixed concrete 4

Table 2.2 Description of RMC in SCOR process.. 12

Table 2.3 SCOR performance attributes 17

Table 2.4 Performance metrics for deliver make-to-order product......................... 19

Table 2.5 Strategic sustainable SCOR metrics.. 20

Table 3.1 Decision Hierarchy of Performance selection in Deliver process........... 28

Table 4.1 Description of RMC in SCOR process.. 33

Table 4.2 AHP result of performance metrics of concrete deliver process............. 37

Table 4.3 Top five selected environmental metrics.. 38

LIST OF FIGURES

Figure **Page**

Figure 2.1 Concrete outbound logistics process 8

Figure 2.2 SCOR model frame work 10

Figure 2.3 SCOR Deliver process framework 15

Figure 2.4 SCOR level2 model of make-to-order product for typical construction supply chain.. 16

Figure 2.5 AHP method framework 23

Figure 3.1 AHP Framework for prioritizing SCOR metrics in RMC Deliver process 25

Figure 3.2 Pair-wise comparison of performance attributes in Deliver process…....30

Figure 4.1 SCOR high level deliver process framework 31

Figure 4.2 Global score of performance metrics 36

Figure 4.3 Consistency Ratios of criteria and sub criteria 38

LIST OF DEFINITIONS

SCOR	Supply Chain Operations Reference
RMC	Ready Mixed Concrete
AHP	Analytical Hierarchy Process
CO_2	Carbon dioxide

CHAPTER 1

INTRODUCTION

1.1 Research Background

Ready mixed concrete (RMC) industry plays important role in infrastructure development. For the past four years, the demand of concrete has increased 14 million cubic meters of concrete per year (BoT, 2017a). That means 14 million cubic meters of RMC were delivered to job sites by RMC truck mixers.

There are often RMC problems occur in deliver process such as late delivery, non-conforming concrete order, and lack of clear communication. Different concrete project types mean slightly using different rules in delivery. The typical deliver process of RMC consists of truck loading from batching plant to unloading at construction site and returning to batching plant. That involves three main parties include customers, sales, and operation team. Customer places order, while sale and operation team interact with customers in delivering concrete to fulfill the order. In this regard, there is a need of using framework to map process and measure performance in concrete industry. Supply Chain Operations Reference (SCOR) model has been implemented by organizations for their supply chain improvement and performance. SCOR consists of process elements of Source, Make, Deliver, and Return respectively with its performance metrics. This paper aims to implement the SCOR model to ready mixed concrete supply chains in scope of deliver process and performance metrics. This study contributes to ready mixed concrete logistics and supply chain managers to monitor and select important performance metrics for their supply chain operations.

1.2 Statement of the Problem

Ready mixed concrete has lots of benefits to construction project due to its durability and the flexibility in transporting. However, there are many concerns regarding RMC supply chain such as high cost of production, not in committed time delivery request, and environmental impacts such as dust pollution and concrete wastes. SCOR model is proposed in this study as method for supply chain process mapping, documenting, evaluating performances in ready mixed concrete supply chain. Therefore, this study focuses on the following research questions:

- How practical is it to map RMC supply chain process with SCOR model?
- What important SCOR strategic metrics are ideally suitable used in RMC supply chain?
- What are important environmental metrics for RMC industry based on management level's perception?

1.3 Objectives of the Study

The objective of this study is to apply SCOR model to RMC supply chain. Specifically:

- To map RMC supply chain with SCOR processes

- To find key critical strategic SCOR metrics for RMC supply chain performance in domain of deliver process.
- To find important strategic environmental performance metrics for RMC.

1.4 Scope of the Study

The study will investigate a case of one RMC supplier in Bangkok, Thailand. The company has 5 batching plants and 65 mixing trucks operating in Bangkok areas. The company can supply 8,000 cubic meters of fresh concrete per month. This study focuses on domain of deliver process of SCOR, specifically modeling deliver process of Ready Mixed Concrete starting from the supplier's batching plants to customer's construction sites by using SCOR model.

CHAPTER 2

LITERATURE REVIEW

2.1 Ready Mixed Concrete Industry

As shown in **Table 2.1**, Concrete is a common construction material that composed of four main components; cement, water, and aggregates (crushed stones and sand). Other components are used to make special design of concrete such as fly ash, chemical admixture. Once materials are combined, they become ready mixed concrete which is the special product that is perishable with time and make-to-order product.

Table2.1 Typical Mix Design of Ready Mixed Concrete

Inputs	Ready Mixed Concrete
Air	6%
Cement	10%
Water	18%
Sand	25%
Crushed Stones	41%

Therefore, the planning of producing concrete must be highly accurate to actual production volume and time. The availability of materials must be enough for producing to fulfill the demand. Usually, RMC supplier discusses the concrete work plan with customer in very detail like specific mix designs, volume, casting date and time, and other special requirements for inventory planning. Ready mixed concrete is perishable products and it is a Made-to-Order product, mix design according to customer's specific requirements. Customers or usually as contractors look for RMC suppliers or vendors that can fulfill the requirements such as quality, price, and service. Just in time delivery is crucial for concrete work operation at sites. The common problem in RMC delivery is late delivery that cause big problems since concrete has short life cycle time. If concrete exceeds its certain time constraint, it will be unusable because of cold joints problem, harden time of concrete. That is the reason RMC plant provides service in a certain limited region.

For RMC suppliers usually use their experiences with manual tasks to deal with problems that gradually lower customer's satisfaction or service level. To this extend, many studies with different methods associates in RMC deliver process. (Park, Kim, Lee, & Han, 2011) presents supply chain management model for RMC such as genetic algorithms(GA), Neural Networks, bee colony, fuzzy multi-objective linear program. For instance, Feng et al. (2000) generated problems and built a systematic model to solve RMC scheduling problems using genetic algorithms (GA) to minimize the total wait duration of RMC trucks. Lu and Lam (2005) also proposed optimized concrete delivery scheduling using GA. Graham (2006) presented a neural network to solve RMC problems. Feng's research using bee colony optimization compared to GA and Tabu search focusing on single plant delivery to 3, 5 and 9 sites for three concrete types. Su (2013) presented the fuzzy multi- objective linear program to analyze the cost-effectiveness of vehicles.

In RMC industry, materials for producing concrete are Source-to-stock, while concrete itself is Make-to-order. The supply chain process from source, make, deliver, and return of RMC is described below:

1. Source: all materials required for producing concrete are source-to-stock products for combining by mixing machine at batching to fulfill the customer order. The common stocked materials are water, cement, and aggregates (river sand and crushed stones).
    - Cement: is main ingredient for producing concrete. Cement is the binding agent that combine sand and crushed stones together once mixed with water. Cement emits the most CO2 emissions because the processing of manufacturing cement is the burning process that requires lots of energy.
    - River Sand: can be found in bottom of river. The process of extracting river sand is quite simple and consume relatively small energy but excessive mining of the sand cause major impacts to river ecosystems such as marine lives, and river bank erosion.
    - Crushed Stones: is a material to make concrete to gain mass. They are in different sizes. The typical process of getting crushed stones come from mining mountain rocks or other big rock area by defragmenting using explosive procedures and breaking the rocks down by crushers.

2. Make: concrete is a make-to-order product. It is made when only needed. All components are stocked ready to put in concrete mixing machine to make fresh concrete.

3. Deliver: the delivery process of ready mixed concrete is challenging because of limited time of delivery. The proper planning of mixing trucks, and timing& scheduling are important to have smooth deliver operation. It is quite challenging for RMC suppliers to deliver their products to job sites time constraint since concrete is perishable and must be delivered within certain time window. Production errors, traffic congestions, and job site work delay are main concerns in deliver process. For instance, if concrete exceeds its certain time constraint, it will be unusable. That is the reason RMC plant provides service in a certain limited region.

4. Return: when arrived at jobsite, the test will be conducted before casting and non-conforming fresh concretes shall be returned after failing test such slump test, air quantity test. Problems may occur when mixing trucks broken, or traffic congestion while transporting that cause the delay lead to the change of concrete requirement at jobsite. Concrete is perishable product, within limited time constraints to be delivered to jobsites.

2.2 Ready Mixed Concrete Supply Chain Operation Process

The demand of concrete in Thailand has been dramatically increasing since 2000, 5 million m^3 to 14 million m^3 per year tween 2013 and 2016 (BoT, 2017b). This statistic data indicates that the urban infrastructure development activities has been so active, and expansion of urban development is relatively fast. With this regard, there are more concerns on environmental impacts. According to Bank of Thailand data as illustrated in Appendix A for domestic concrete sales information, 190 million cubic meters concrete has been sold in the past 16 years.

2.3 Ready Mixed Concrete Outbound Logistics Process

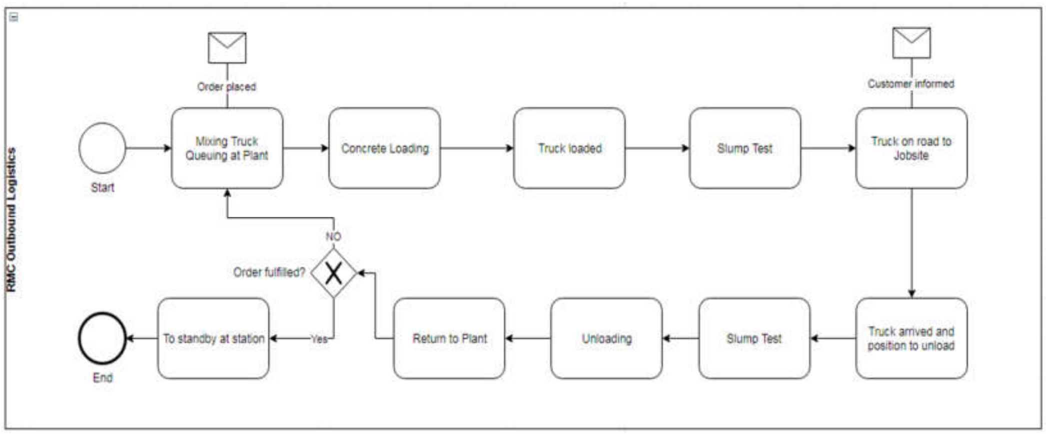

Figure 2.1 Concrete outbound logistics process.

Outbound logistics of RMC starts customer order to order fulfillment as shown in **Figure 2.1**. The performance of truck mixers depends on the type of concrete placement methods used on-site. Truck mixer drivers take an average of 1.55 min to position their truck mixers and 1.23 min to load them. Before leaving the plant, each batch of delivery must go through the slump test to ensure that the ready mixed concrete is of correct workability. To identify the processes of RMC production and delivery, the concrete batching operation of a local company in Thailand was observed. Site observations were made on a sample size of 100 deliveries whereby each batch of RMC, from the material supply to delivery on-site, was monitored. The identified RMC operation processes and their performance data were used to build and test the research model described in the following section. The full carrying capacity of a truck mixer is 6 m^3. Truck mixer drivers are on standby to receive a work order, responding immediately if the plant runs out of truck mixers. It is challenging for RMC suppliers to deliver their products to job sites time constraint since concrete is perishable and must be delivered within certain time window. Production errors, traffic congestions, queuing at job site, job site delays are main concerns in deliver process.

2.4 SCOR Model

Organizations or enterprises build supply chain process modeling to view processes as a whole, to see through hidden critical sub processes, to see linkages of each activities in processes or another word to control fragmentation between functional silos or departments and systems with companies (Davenport, 1993). There are number of literatures that apply supply chain frameworks for process modeling. For instance, in year 2000 Lambert and Cooper proposed the Global Supply Chain Forum (GSCF) framework that consists of strategic perspective and focuses on integration and relation among functional units.

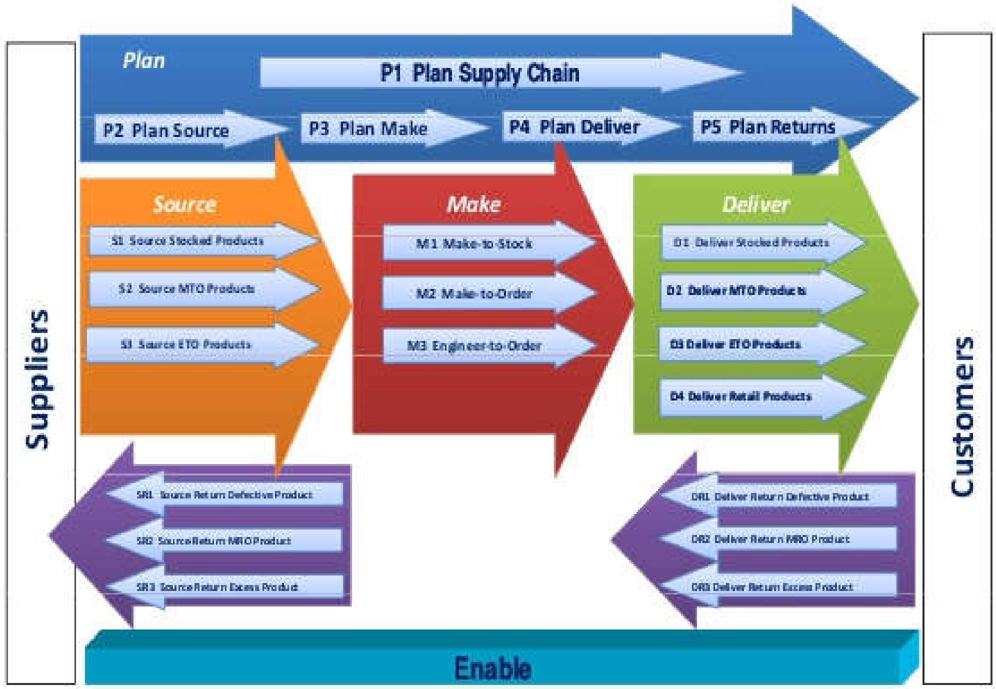

Figure 2.2 SCOR model framework

Source: APICS. 2017. SCOR 12.0.

As shown in **Figure 2.2**, SCOR framework consists of process plan, source, make, deliver, return, and enable. These five strategic processes breakdown into sub-process elements in level 3, and tasks activities in level 4. Many researches on SCOR has been studied. There were 45 papers of SCOR model has been reviewed in deferent perspectives (Ntabe, LeBel, Munson, & Santa-Eulalia, 2015). Companies use SCOR model to configure, benchmark, and do performance analysis of their supply chains. SCOR improves supply chain performance, sales and operations planning. The framework also helps design process system and build blue print from as-is to-be in organization. Many leading companies and practitioners adapted SCOR framework to their supply chain and business process design and implementation. In order to get higher level of understanding of processes, create operational transparency, and create roles and responsibility of each functions to complete their process tasks and activities. It is a cross functional flow chart where process components are grouped into responsible functional lane. It builds an integrated process map across the organization that can be diagnosed for improvement. It helps clarify complex processes such as department and team responsibility, the relationship teams, steps and overall process, and overview of process map in specific details.

2.4.1 SCOR Processes

Practitioners are adopting SCOR because of some benefits. SCOR improves supply chain process and performance. The framework also helps design process system and build blue print from as-is to to-be in organization, process design. With latest version of SCOR 12.0 is much focus on operational circles by adding new enable process (Newman, 2013). Many researches on SCOR has been studied. For instance, There were 45 papers of SCOR has been reviewed in deferent perspectives (Ntabe, LeBel, Munson, & Santa-Eulalia, 2015). Processes in SCOR have been identified as unique processes with process hierarchy and scope. SCOR processes comprise of plan, source, make, deliver, return, and enable as shown in **Table 2.2** below.

Table 2.2 Description of RMC in SCOR processes

Hierarchy	Ready Mixed Concrete Supply Chain Under SCOR Framework
sS1	Source-to-Stock
sS1.1-sS1.5	The process of ordering, receiving and transfer raw material items such as cement, sand, and aggregates based on demand forecast. RMC supplier usually order materials to maintain inventory, safety stock.
sM2	Make-to-Order
sM2.1-sM2.7	The process of mixing concrete based on standard customer specific order, slump test at plant, manage waste after production at batching plant
sD2	Deliver Make-to-Order Product
sD2.1-sD2.15	The process of loading concrete from bathing plant, deliver, waiting and unloading at jobsite.
sR	Return
sSR1	Source Return Defective Product
sSR1.1-sSR1.5	The return and disposition determination of defective products as defined by the warranty claims, non-conforming product. RMC supplier uses business rules or contract to determine defective materials. Example of defective materials are low quality sand and crushed stones. Usually Quality Control team determine whether materials are defective.
sDR1	Deliver Return Defective Product
sDR1.1-sDR1.4	The return of defective or non-conforming concrete from jobsites. Causes of return can be late delivery because of traffic congestion or incident at jobsites. Because fresh concrete is perishable product with time, maintaining quality of concrete on delivery is crucial.

- Plan: this process describes activities associated with developing plans to operate the supply chain. The Plan process includes the gathering of requirements, gathering of information on available resources, balancing requirements and resources to determine planned capabilities and gaps in demand or resources and identify actions to correct these gaps.

- Source: this process describes the ordering (or scheduling of deliveries) and receipt of goods and services. The Source process embodies the issuance of purchase orders or scheduling deliveries, receiving, validation and storage of goods and accepting the invoice from the supplier. With the exception for sourcing Engineer-to-Order goods or services, all supplier identification, qualification and contract negotiation processes are not described using Source process elements
- Make: this process describes the activities associated with the conversion of materials or creation of the content for services. Conversion of materials is used rather than ‘production’ or ‘manufacturing’ as Make represents all types of material conversions: Assembly, Chemical processing, Maintenance, Repair, Overhaul, Recycling, Refurbishment, Remanufacturing and other common names for material conversion processes. As a general guideline, these processes are recognized by the fact that one or more item numbers go in and one or more different item numbers come out of this process.
- Deliver: this process describes the activities associated with the creation, maintenance and fulfillment of customer orders. The Deliver process embodies the receipt, validation and creation of customer orders, scheduling order delivery, pick, pack and shipment and invoicing the customer. The sD4 Deliver Retail process provides a simplified view of Source and Deliver processes operated in a Make-to-Stock-only retail operation.

- Return: The Return processes describe the activities associated with the reverse flow of goods. The Return process embodies the identification of the need to return, the disposition decision making, the scheduling of the return and the shipment and receipt of the returned goods. Repairing, recycling, refurbishment and remanufacturing processes are not described using return process elements.
- Enable: this process describes the associated with the management of the supply chain. Enable processes include management of business rules, performance management, data management, resource management, facilities management, contract management, supply chain network management, managing regulatory compliance and risk management. For each level-1 process 3 or more differentiating level-2 process categorizations exist. Each level-2 process contains level-3 process elements. These hierarchical relationships provide classification of processes. The processes associated with establishing, maintaining and monitoring information, relationships, resources, assets, business rules, compliance and contracts required to operate the supply chain. Enable processes support the realization and governance of the planning and execution processes of supply chains. Enable processes interact with processes in other domains such as financial processes, human resource processes, information communication & technology processes, facilities management processes, product & portfolio management processes, product and design processes, and sales & support processes.

2.4.2 SCOR Deliver Process

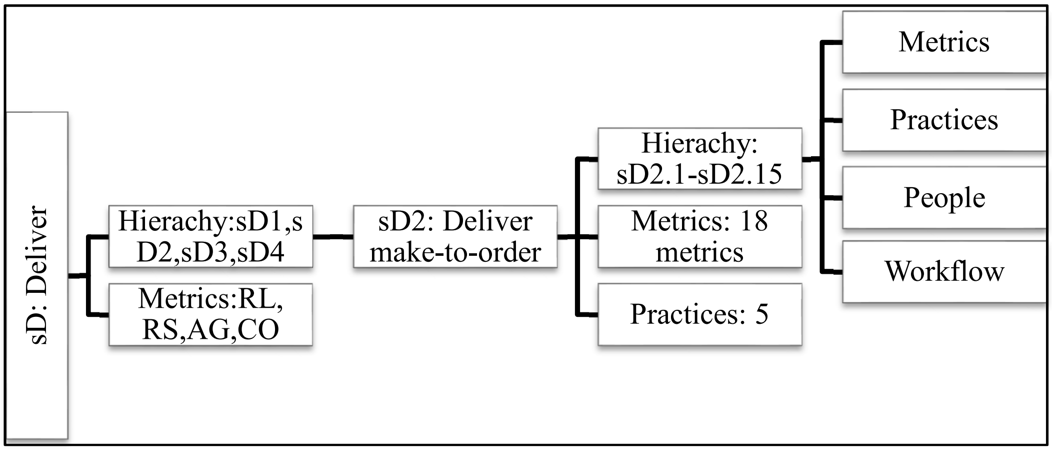

Figure 2.3 SCOR Deliver process framework

In process deliver process, as shown in **Figure 2.3**, consists of process hierarchy that define four different characteristics of products to deliver. For instance, sD2 means deliver make-to-order product, which ready mixed concrete. In the process diver make-to-order consists of its hierarchy, metrics and practices. In this level 3 process of SCOR 12.0 framework also workflow and people, human skills needed to put in process. Figure 2.4 shows the construction product that is considered as make-to-order that is mapped at level 2 in SCOR model framework.

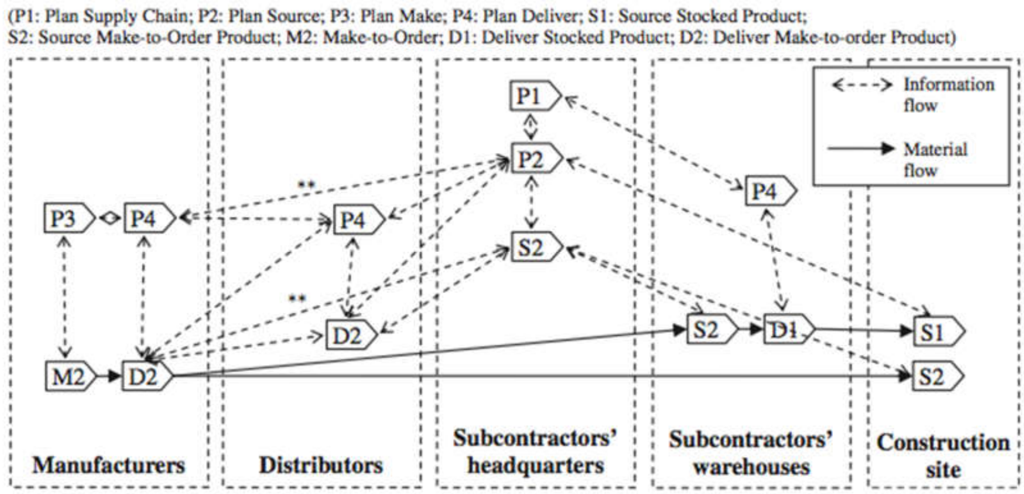

Figure 2.4 SCOR level2 model of make-to-order product for typical construction supply chain

Source: Cheng, J. C. P., Law, K. H., Bjornsson, H., Jones, A., & Sriram, R. D. (2010). Modeling and monitoring of construction supply chains.

2.4.3 SCOR Performance Metrics

SCOR model consists of performance metrics under five attributes for assessment and measurement of supply chain processes. Performance attributes are strategic characteristics of supply chain performance for strategic directions of the company, it is a categorization of metrics used to express a specific strategy as shown in **Table 2.3**. Metrics are discrete key performance indicators with its connected hierarchy level.

Table 2.3 SCOR performance attributes

SCOR Performance Attribute		
Facing	Attribute	Strategy
Customer	Reliability	Consistently getting the orders right, product meets quality requirements
	Responsiveness	The consistent speed of providing products/service to customers
	Agility	The ability to respond to changes in the market (external influences)
Internal	Cost	The cost associated with managing and operating the supply chain
	Assets	The effectiveness in managing the supply chain's assets in support of fulfillment

- Reliability: The Reliability attribute addresses the ability to perform tasks as required. Reliability focuses on the predictability of the outcome of a process. Metrics for the Reliability attribute include: On-time, the right quantity, and with the right documentation. The SCOR key performance indicator (level-1 metric) is Perfect Order Fulfillment. Reliability is a customer focused attribute.
- Responsiveness: The Responsiveness attribute describes the speed at which tasks are performed. Responsiveness addresses repeated speed of doing business. Examples of Responsiveness metrics are cycle time metrics related to speed to source, to make, and to deliver. The SCOR key performance indicator for Responsiveness is Order Fulfillment Cycle Time. Responsiveness is a customer focused attribute.
- Agility: The Agility attribute describes the ability to respond to external influences; the capability and speed of change. External influences include non-forecast able increases or decreases in demand, suppliers or partners going out of business,

natural disasters, acts of (cyber) terrorism, availability of financial resources (the economy), labor issues. The SCOR key performance indicators include Adaptability and Value-at-Risk. Agility is a customer focused attribute.

- Cost: The Cost attribute describes the cost of operating the supply chain process. Typical costs include labor, materials, systems, and transportation costs. The SCOR key performance indicators for Cost are Total Supply Chain Management Cost and Cost of Goods Sold (COGS).
- Asset Management Efficiency: The Asset Management Efficiency ("Assets") attribute describes the ability to efficiently utilize assets. Asset management strategies in supply chain include inventory reduction and insource vs. outsource. Example metrics include: Inventory days of supply, capacity utilization. The SCOR key performance indicators include: Cash-to-Cash Cycle Time, Return on Fixed Assets. Asset Management Efficiency is an internal focused attribute.

In the deliver process of make-to-order product has totally 18 performance metrics as shown in table 3. These strategic metrics has its down level of metrics respective to the process.

Table 2.4 Performance metrics for deliver make-to-order product.

Metrics for sD2 Deliver Make-to-Order Product	
KPI 1	RL.1.1 Perfect Order Fulfillment
KPI 2	RS.1.1 Order Fulfillment Cycle Time
KPI 3	RS.2.3 Deliver Cycle Time
KPI 4	RS.3.20 Current logistics order cycle time
KPI 5	AG.2.3 Upside Deliver Adaptability
KPI 6	AG.2.8 Downside Deliver Adaptability
KPI 7	AG.3.1 % of labor used in logistics, not used in direct activity
KPI 8	AG.3.4 Additional Delivery volume
KPI 9	AG.3.32 Current Delivery Volume
KPI 10	CO.2.4 Cost to Deliver
KPI 11	CO.3.14 Order Management Costs
KPI 12	CO.3.15 Order Delivery and / or Install Costs
KPI 13	CO.3.21 Risk Mitigation Costs (Deliver)
KPI 14	AM.1.1 Cash-To-Cash Cycle Time
KPI 15	AM.1.2 Return on Supply Chain Fixed Assets
KPI 16	AM.1.3 Return on Working Capital
KPI 17	AM.3.17 Inventory Days of Supply - WIP
KPI 18	AM.3.45 Inventory Days of Supply - Finished Goods

2.4.4 Environmental SCOR Performance

Business sustainability practices are increasingly focused among business corporations around the world. Thus, sustainable supply chain practices become standard for business organizations to follow different industries. The version of SCOR 12.0 framework consists of environmental accounting metrics for sustainable SCOR for industry to use as initiative approach to take environment concerns in their supply chain. Concrete industry associations or firms can use this sustainable SCOR framework to gain opportunities and competitiveness. **Table 2.5** shows 23 strategic sustainable SCOR metrics.

Table 2.5 Strategic sustainable SCOR metrics.

Sustainable SCOR	
KPI 1	Total Supply Chain Materials Used
KPI 2	Total Supply Chain Materials Intensity Ratio
KPI 3	Total Supply Chain Non-Renewable Materials Used
KPI 4	Total Supply Chain Renewable Materials Used
KPI 5	Total Supply Chain % of Recycled Input Material Used
KPI 6	Total Supply Chain % of Reclaimed Products and Their Packaging Materials
KPI 7	Total Supply Chain Energy Consumed
KPI 8	Total Supply Chain Non-Renewable Energy Consumed
KPI 9	Total Supply Chain Renewable Energy Consumed
KPI 10	Total Supply Chain Energy Intensity Ratio
KPI 11	Total Supply Chain Reduction of Energy Consumption
KPI 12	Total Supply Chain Water Withdrawn
KPI 13	Total Supply Chain Water Reused or Recycled

KPI 14	Total Supply Chain Water Intensity Ratio
KPI 15	Total Supply Chain Greenhouse Gas (GHG) Emissions
KPI 16	Total Supply chain GHG Emissions Intensity Ratio
KPI 17	Reduction of GHG Emissions
KPI 18	Total Supply Chain Emissions of ozone-depleting substances (ODS)
KPI 19	Total Supply Chain Nitrogen oxides, sulfur ozides, and other significant air emissions
KPI 20	Total Supply Chain Air Emissions
KPI 21	Total Supply Chain Water Discharge
KPI 22	Total Supply Chain Non-Hazardous Waste
KPI 23	Total Supply Chain Hazardous Waste

National Ready Mixed Concrete Association, USA (NRMCA, 2012) stated the carbon emission from concrete is 100 kg to 300kg per cubic meter based on mix design. On average is 200 kg-CO_2 per one cubic meter. So, the approximately 32 million ton-CO_2 has been released since 2000. Because the one of inputs of concrete is made of cement, which needs large amount of energy to produce. Sand and aggregates like crushed stones also have the impacts to environment. For instance, excessive river sand mining may cause river bank erosion consequences in long term (Thornton et al., 2006). The process of making crush stones cause noises and dusts impacts at surrounding area.

To understand the relationship between RMC and CO_2, the composition of concrete is revealed. Basic inputs to make RMC are cement, water, sand, crushed stones, and other ingredients such as fly-ash and admixtures. The most embodied component of concrete is cement because it uses lots of energy in manufacturing cement. Other processes like extracting river sand and mining crushed stones, mixing concrete and transporting to jobsite relatively consume small amount of energy thus emits small amount of CO_2. Since of high building structures, mega structures like dam, foundation, required high compressive strength concrete meaning higher cement ratio in concrete that emits more CO_2 comparing the same amount concrete to build typical housing projects. In shorts, RMC manufacturing produces most of its carbon Emissions from amount of cement input according to concrete mixed design. Mixing and delivering processes produce very little amount of CO_2.

United Nations country members agreed on 17 development goals to end poverty, protect the earth, and provide prosperity to all humanity (UN, 2015). One of the goals is for business to take urgent action to combat and address climate change and its impacts since business activities produce carbon emissions. The cause of global warming is from CO_2 emissions since CO_2 remains in the atmosphere longer than the other green-house gases (UCSUSA, 2017).The amount of carbon emissions from ready mixed concrete supply chain if greatly come from cement manufacturing, other processes like mixing and transporting emit relatively low CO_2. Thus, the focus on reducing carbon emissions in RMC industry is cement manufacturing industry.

Climate change can be both risk and opportunity for firms in considering their environmental performance for business sustainable growth. The agreement also provides guideline for business to take action such as reducing CO_2 emissions in their supply chain operations, improve the use of energy efficiency, and plan targeted carbon emissions in their operation, investing in Research& Development of innovative low-carbon product, and be adaptive to climate change (UN, 2016).

2.5 AHP Method in SCOR Model

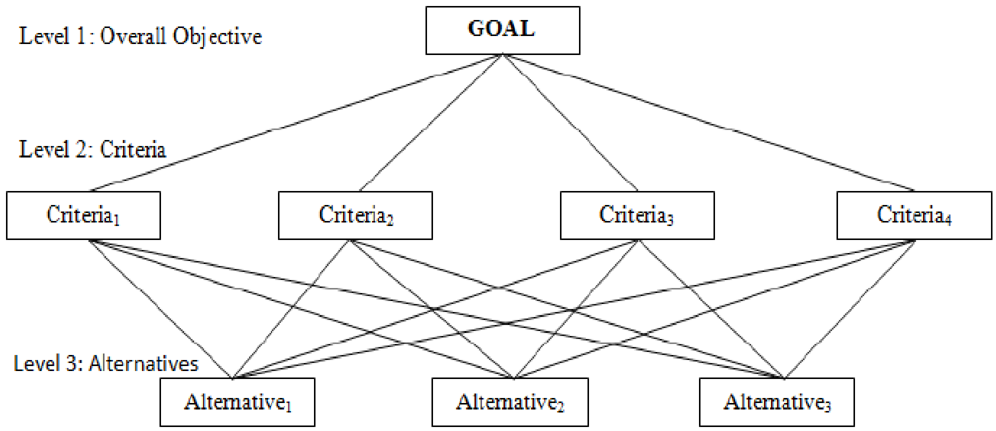

Figure 2.5 AHP method framework

Source: Agarwal, Prince & Sahai, Manjari & Mishra, Vaibhav & Bag, Monark & Singh, Vrijendra. (2014). Supplier Selection in Dynamic Environment using Analytic Hierarchy Process. International Journal of Information Engineering and Electronic Business.

Analytical Hierarchy Process method is a mathematical method for analyzing complex decision problems under multiple criteria (Saaty, 1995) as shown in **Figure 2.5**. AHP method has been used as an effective decision tool by business practitioners and researchers in complex decision making. The AHP method consists of four steps of procedure:

- Categorize complex problem into multiple level, called criteria.
- Pair-wise comparison of criteria to weigh relative criteria for level of importance by using nine-point scale of preference.
- Relative weight calculation by normalized vector of priorities in the matrix.
- Checking Consistency of the pair-wise comparison to ensure the judgment of expert knowledge is consistent.

In this study the method is used to differentiate the degree of importance of SCOR metrics in concrete supply chain base on managerial level's perception. It is a tool for critical SCOR metrics selection. The metrics are codified to align with its performance attributes. For example, RL.1.1 Perfect Order Fulfilment is under Reliability attribute. There are some studies using SCOR and AHP method combined to investigate the poor or critical supply chain performances. For instance, Bukhori uses AHP to get three critical performance metrics in each of SCOR processes from plan, source, make, deliver and return in a case study of poultry supply chain and find the root causes by using cause& effect or fishbone diagram, (Bukhori, Widodo, & Ismoyowati, 2015). Another research by Palma also points out the usage of AHP method to help decision for selecting better supply chain re-design processes (Palma-Mendoza, 2014). Francisco proposes supplier evaluation by using SCOR metrics and fuzzy toppsis, extended AHP to prioritize supplier's performance and to categorize suppliers base on their performance in scope of cost and delivery performance. Another researcher tries to link SCOR framework standard processes and supply chain strategy by using AHP method to prioritize a company's strategy on each process base on customer's demand (Alomar & Pasek, 2014).

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Conceptual Framework

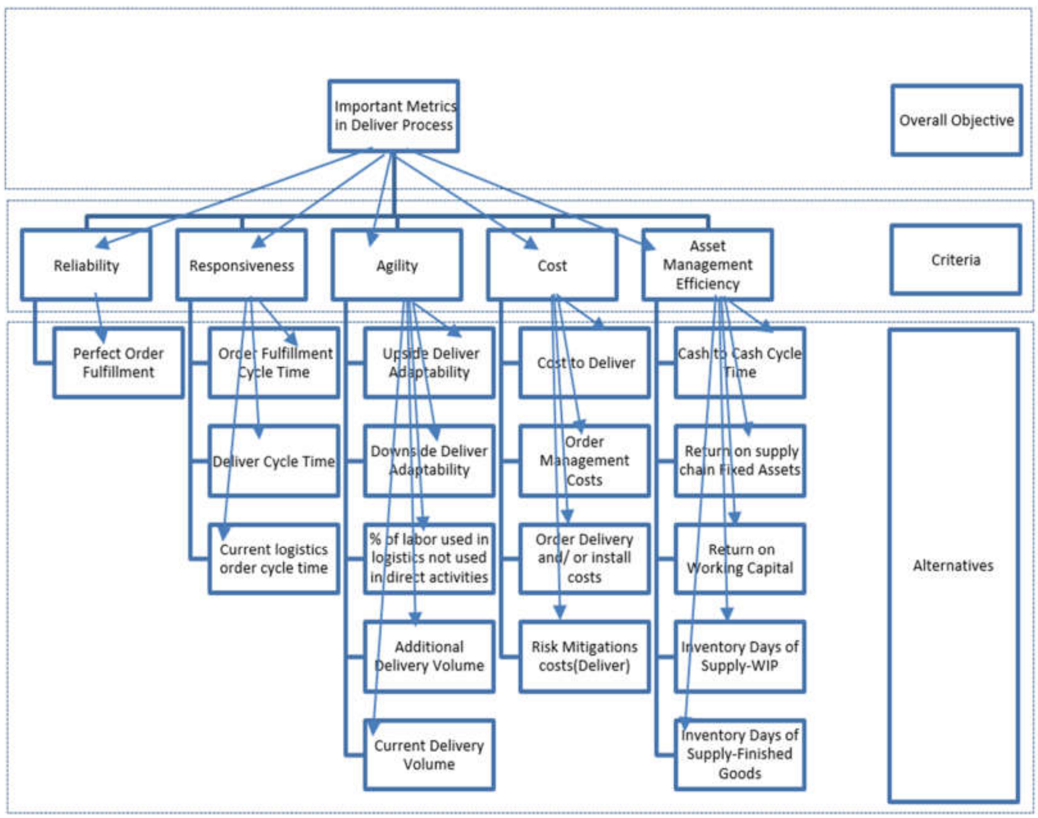

Figure 3.1 AHP Framework for prioritizing SCOR metrics in RMC Deliver Process

The approach of this study is to map the RMC supply chain with SCOR model framework in the domain of deliver process, and to identify critical or important strategic performance metrics by using Analytical Hierarchy Process method to prioritize the performance metrics as shown in **Figure 3.1**. In this regard of applying AHP, the expert knowledge is required for assuring quality of the output. Therefore, the interview with logistics expert of RMC is conducted.

3.2 Research Design

An interview questionnaire for an expert knowledge, which is logistic manager, is designed to make pair-wise comparison of level 2 metrics which consists of four metrics, and pair-wise comparison of level 3 metrics. The questionnaire as shown in the Appendix B, by using 9 scale of importance level from 1 equally important to 9 extremely important. This AHP method questionnaire is for knowledge expert meaning logistics or production management level to give score of each comparison. To determine the expert knowledge of deliver process, an interview with logistics manager or production manager is conducted with expert intention of participation.

Three dimensions of SCOR framework includes process, performance metrics, and sustainable SCOR are studied in this case study of concrete supply company in Bangkok. For the ease of filling up the questionnaire, each metric will be clearly explained to make pair-wise comparison. The questionnaires will be handed to experts in managerial level of the company. The time for completing the questionnaire should be 20 to 30 minutes. This pair-wise comparison questionnaire can be labor intensive and time consuming since it requires expert to make comparison of every metrics. The researcher prepared documents and designed questionnaires form for an interview appointment with participant. Managerial level is to be interviewed. Questionnaire titled "Application of SCOR in Concrete Supply Chains" consist of three sections:

1. Section A: personal data of respondents
2. Section B: selection of important SCOR metrics in concrete supply chains with pair-wise comparisons in analytic hierarchy process (AHP).
3. Section B: sustainable SCOR performance metrics

3.3 Method of Data Analysis

The completed questionnaire is collected for data analysis after the interview with expert knowledge. SCOR metrics in concrete delivery process are taken for pairwise comparison by using AHP web application calculator developed by Klaus D. Goepel (Goepel, 2017). Klaus developed this AHP calculator for his consulting company (Business Performance Management Singapore (BPMSG) for professional business performance decision. As shown in **Table 3.1**, at level 0 is the objective or goal of important metrics. Strategic performance metrics that consist of Reliability, Responsiveness, Agility, Cost, and Asset Management are in level 1 for first pair-wise comparison, then the sub-criterial under each strategic metrics are chosen for second pair-wise comparison at level 2. At the final step is to combine all weight together to get one global weight of AHP comparison.

Table 3.1 Decision Hierarchy of Performance selection in Deliver process

Decision Hierarchy		
Level 0	Level 1	Level 2
SCOR Metrics Selection_Deliver Process	Reliability(Perfect Order Fulfillment)	
	Responsiveness	Order Fulfillment Cycle Time
		Deliver Cycle Time
		Current logistics order cycle time
	Agility	Upside Deliver Adaptability
		Downside Deliver Adaptability
		% of labor used in logistics
		not used in direct activity
		Additional Delivery volume
		Current Delivery Volume
	Cost	Cost to Deliver
		Order Management Costs
		Order Delivery and / or Install Costs
		Risk Mitigation Costs (Deliver)
	Asset Management	Cash-To-Cash Cycle Time
		Return on Supply Chain Fixed Assets
		Return on Working Capital
		Inventory Days of Supply - WIP
		Inventory Days of Supply - Finished Goods

First step is to develop the weights for the criteria: develop a single pair-wise comparison matrix for the criteria, multiplying the values in each row together and calculating the n^{th} root of said product normalizing the aforementioned n^{th} root of products to get the appropriate weights, and calculating and checking the Consistency Ratio (CR). Step 2 is to develop the ratings for each decision alternative for each criterion by developing a pair-wise comparison matrix for each criterion as shown in

Figure 3.2, with each matrix containing the pair-wise comparisons of the performance of decision alternatives on each criterion; multiplying the values, normalizing, calculating and checking CR. And step 3 is to calculate the weighted average rating for each decision alternative. Choose the one with the highest score. Step 4 is to do consistency analysis, where many pairwise comparisons are performed, some inconsistencies may typically arise. Assume that three criteria are considered, and the decision maker evaluates that the first criterion is slightly more important than the second criterion, while the second criterion is slightly more important than the third criterion. An evident inconsistency arises if the decision maker evaluates by mistake that the third criterion is equally or more important than the first criterion. The sub level of the pair-wise comparison is conducted for four performance metrics respectively to get the global score of comparison.

	A - wrt *SCOR Metrics Selection_Deliver Process* - or B?		Equal	How much more?
1	**Reliability(Perfect Order Fulfillment)**	or Responsiveness	1	2
2	**Reliability(Perfect Order Fulfillment)**	or Agility	1	2
3	**Reliability(Perfect Order Fulfillment)**	or Cost	1	5
4	Reliability(Perfect Order Fulfillment)	or **Asset Management**	1	8
5	Responsiveness	or **Agility**	1	4
6	**Responsiveness**	or Cost	1	2
7	Responsiveness	or **Asset Management**	1	9
8	**Agility**	or Cost	1	4
9	Agility	or **Asset Management**	1	9
10	Cost	or **Asset Management**	1	9

CR = 9.1% OK

Resulting Priorities

	Category	Priority	Rank
1	Reliability(Perfect Order Fulfillment)	13.5%	2
2	Responsiveness	5.5%	4
3	Agility	11.4%	3
4	Cost	3.5%	5
5	Asset Management	66.1%	1

Figure 3.2 Pair-wise comparison of performance attributes in Deliver process.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Deliver Process modeling with SCOR Framework

This section presents the results of outbound logistics of ready mixed concrete with SCOR framework. Therefore, there are two modeling results which are from SCOR framework for strategic process as shown in **Figure 4.1**. In the scope of SCOR framework, 15 processes at level 3 of deliver make-to-order process captures concrete outbound logistics process.

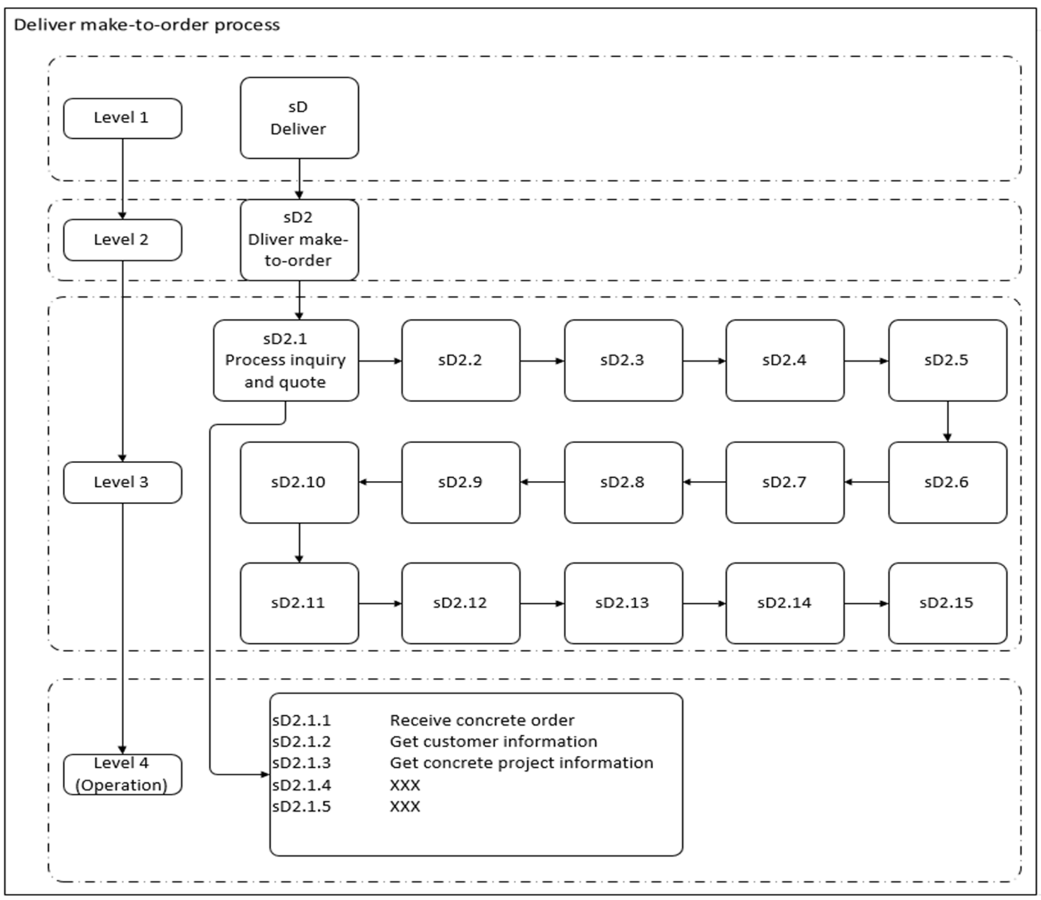

Figure 4.1 SCOR high level deliver process framework

The 18-performance metrics at level 3 correspond each level 3 process accordingly. For instance, the process sD2.1 process inquiry and quote consist of sub processes at level 4 which is operational process consisting of processes sD2.1.1 receive concrete order, and so on. Some of these sub processes in level 4 could be changed anytime base on process flexibility like process sD2.1.4 and sD2.1.5. The Table 4.1 below shows the description of RMC deliver process under SCOR deliver process respectively at level 3. However, not all these processes accurately align with the concrete outbound logistics processes since there are some unique processes in outbound logistics like returning to the plant to refill the loads.

The standard SCOR model is necessary tool to diagnose and evaluate supply chain for better decision making. For ready mixed concrete industry, deliver process or outbound logistics is very critical to many RMC suppliers as they need to overcome challenges such as committing to on time delivery with standard quality and concrete itself is perishable product that must be delivered within a limited setting time. In SCOR version 12.0, deliver process at level 2 include deliver stocked product (sD1), deliver make-to-order (sD2), and deliver engineer-to-order (sD3). In standard RMC industry, the product can be defined as deliver make-to-order because concrete is produced only when there is an order from customer. It is can also be defined as deliver engineer-to-order when there is a special mix design of concrete for specific usage which is not in standard mix design.

Table 4.1 Description of RMC in SCOR processes	
Hierarchy	Description
sD2: Deliver Make-to-Order Product	Ready mixed concrete is a perishable product and it made only when the order is placed.
sD2.1-sD2.15	Fifteen SCOR deliver process of loading concrete from bathing plant, deliver, waiting and unloading at jobsite.
sD2.1: Process Inquiry and Quote	Receive and respond to customer inquiries and requests for concrete price quotations.
sD2.2: Receive, Configure, Enter, and Validate Order	Orders are received from customer enter them into company's order system. Concrete order usually is received via phone call for details customer's specific requirements of concrete such as volume, strengths, slump, and other additional requirements in order to provide accurate pricing. Then sale team check for customer's credit and payment term. Sale contract is signed with customer at this point.
sD2.3: Reserve Inventory and Determine Deliver Date	Operation team, production team, and purchase team start to identify available materials such sand, crushed stones, and cement for preparation to fulfill the order. Deliver time & date and specific conditions are planned at this process.
sD2.4: Consolidate Orders	Analyzing orders with other customers to find the concrete project site groupings for cost reduction and better service

	fulfillment. For instance, determining nearest batching plants to the job site for less cost of concrete transportation.
sD2.5: Build Loads	Transportation is determined, and efficient loads of concrete is planned for each mixing truck.
sD2.6: Route Shipments	Determine optimized or shortest road to concrete jobsite. Concrete supplier needs to plan for some roads to construction site that are limited and regulated for concrete truck such as downtown area and restricted area.
sD2.7: Select Carriers and Rate Shipments	Specific mixing trucks and drivers are selected based on their expertise of jobsite area so that it saves cost of transport.
sD2.8: Receive Product from Source or Make	Activities such as receiving input materials, verify, recording product receipt and recording location of materials from production and purchasing, including quality inspection as well.
sD2.9: Pick Product	Activities including retrieving sands, cements, and other input materials, verifying inventory availability, picking materials, recording materials for concrete production.
sD2.10: Pack Product	Activities such as mixing concrete, paste product codes, and preparing concrete truck queuing for loading.

sD2.11: Load Product& Generate Shipping Docs	Series of tasks including placing fresh concrete from silo into mixing trucks and generating deliver order and other documents to comply with other parties.
sD2.12: Ship Product	The process of delivering fresh concrete from batching plant to customer concrete jobsite.
sD2.13: Receive and Verify Product by Customer	The process of receiving concrete at jobsite, verifying the correct order and meet the delivery terms. Customer then receive and sign delivery order to accept the concrete.
sD2.14: Install Product	The process of preparing mixing truck for unloading concrete such as on-site slump test, air pressure test, and strength test. The mixing truck is in position for unloading.
sD2.15: Invoice	Concrete delivery order with customer's signature is sent to financial department for processing invoice for customer to pay according as in sale contract agreement.

4.2 Performance Metrics Selection Priority with AHP

There are 18 performance metrics in Deliver process under 4 strategic attributes or direction. After the pair-wise comparison, the result of metric priority is shown of top three metrics that stand out from other metrics as shown in **Figure 4.2** and **Table 4.2** along with consistency less than 10% in **Figure 4.3**. The AHP result is listed as below:

1. Cash to Cash Cycle Time: 30%
2. Return on Working Capital:24%
3. Reliability: 14%

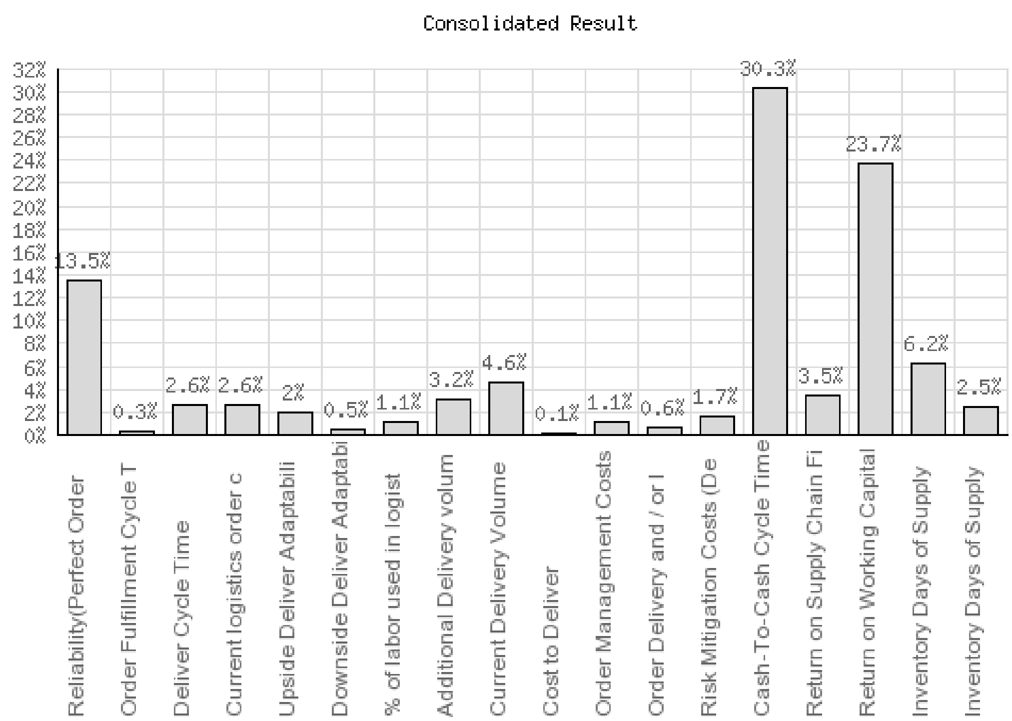

Figure 4.2 Global score of performance metrics

Table 4.2 AHP result of performance metrics of concrete deliver process

Decision Hierarchy			
Level 0	Level 1	Level 2	Glb Prio.
SCOR Metrics Selection_Deliver Process AHP		Reliability(Perfect Order Fulfillment) 0.135	13.5%
	Responsiveness 0.055 AHP	Order Fulfillment Cycle Time 0.059	0.3%
		Deliver Cycle Time 0.471	2.6%
		Current logistics order cycle time 0.471	2.6%
	Agility 0.114 AHP	Upside Deliver Adaptability 0.173	2.0%
		Downside Deliver Adaptability 0.041	0.5%
		% of labor used in logistics not used in dire 0.098	1.1%
		Additional Delivery volume 0.283	3.2%
		Current Delivery Volume 0.405	4.6%
	Cost 0.035 AHP	Cost to Deliver 0.042	0.1%
		Order Management Costs 0.314	1.1%
		Order Delivery and / or Install Costs 0.161	0.6%
		Risk Mitigation Costs (Deliver) 0.483	1.7%
	Asset Management 0.661 AHP	Cash-To-Cash Cycle Time 0.458	30.3%
		Return on Supply Chain Fixed Assets 0.053	3.5%
		Return on Working Capital 0.358	23.7%
		Inventory Days of Supply - WIP 0.093	6.2%
		Inventory Days of Supply - Finished Goods 0.037	2.5%
			1.0

After the two-level pair-wise comparisons, the consistency ratios must be kept below 10% for acceptable result. The first level criteria comparison consists of 5 strategic level performance metrics and the consistency ratio is 9.1%, which is acceptable result. The sub-criterial comparisons are comparisons of alternatives under these strategic metrics. For instance, Reliability strategic metric has only one alternative so it comparison itself. Then, Responsiveness strategic metric has three alternatives for pair-wise comparison with consistency of 0%. Then, Agility strategic metric has 5 alternatives for pair-wise comparison with consistency of 8.9%. Then, Cost strategic metric has 4 alternatives for pair-wise comparison with consistency of 8.9%. Then, the last strategic metric which is Asset Management consisting of 5 alternatives with consistency of 8.1%.

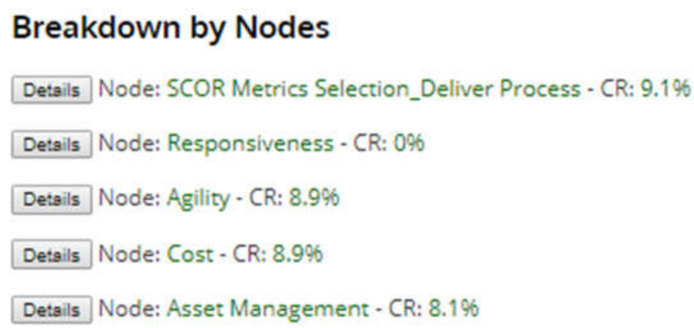

Figure 4.3 Consistency Ratios of criteria and sub criteria

4.3. Environmental Sustainable SCOR Performance metrics Selection

Among 23 sustainable SCOR metrics, there are top five selected metrics that are important to concrete industry according to the perception of management level of the company. The management level is concerning on five environmental metrics, as shown in **Table 4.3**, which are materials, water, and energy in used in the industry, air pollutions such as carbon emissions, and dust pollutions to surrounding environment.

Table 4.3. Top five selected environmental metrics.

Top five Sustainable SCOR	
KPI 1	Total Supply Chain Materials Used
KPI 7	Total Supply Chain Energy Consumed
KPI 15	Total Supply Chain Greenhouse Gas (GHG) Emissions
KPI 20	Total Supply Chain Air Emissions
KPI 21	Total Supply Chain Water Discharge

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study aims to apply SCOR model in ready mixed concrete supply chain in domain of process, performance metrics and environmental accounting in a case study of concrete supply company in Bangkok. The company is chosen due to its availability of data. The research tools used in this study are SCOR model version 12.0 and AHP method. The study focusses mainly on modeling the outbound logistics process of concrete supply and selection process of performance metrics. According to the key findings of the study from face-to-face interview with management levels of the company, the process modeling makes it easier to diagnose some critical problems. The results from AHP method suggests that asset management is critical for doing performance measurement particularly on Cash-to-Cash Cycle Time and Return on Working Capital. Good cash flow is so important for concrete supplier to maintain the business. Customers usually pay in term of bank guarantee meaning very often every month for regular customers and every three months for big volume customers. There are factors such as material used, water discharge, energy, air pollution, and greenhouse emissions that management level of concrete company are concerning for environmental performance of the industry.

5.2 Limitation of the Study

Although this research was carefully prepared, there were some limitations. First, it is a case study research in which its results do not accurately reflect the whole RMC industry in Thailand. Second, because of the time limit, only one expert knowledge person from management level was asked for an interview. In general, to make AHP result more effective and reflect the scope of study, the study should have involved other expert knowledge from other RMC companies in Bangkok too. Therefore, the results of the study are generalized and more consistent. However, it still does not imply larger scope in Thailand.

5.3 Recommendations

The results of this study will be useful for people works in concrete industry in Thailand for supporting their decision making about modeling their business process in their own context with SCOR model. The study points out critical performance metrics for their critical strategic directions of the company. Moreover, the study introduces environmental performance metrics in concrete supply chain as initiative approach for sustainable business development in concrete industry in the future. Future researchers can further study on other scopes of SCOR model such as Source, Make, Return, and Enable process on RMC supply chain.

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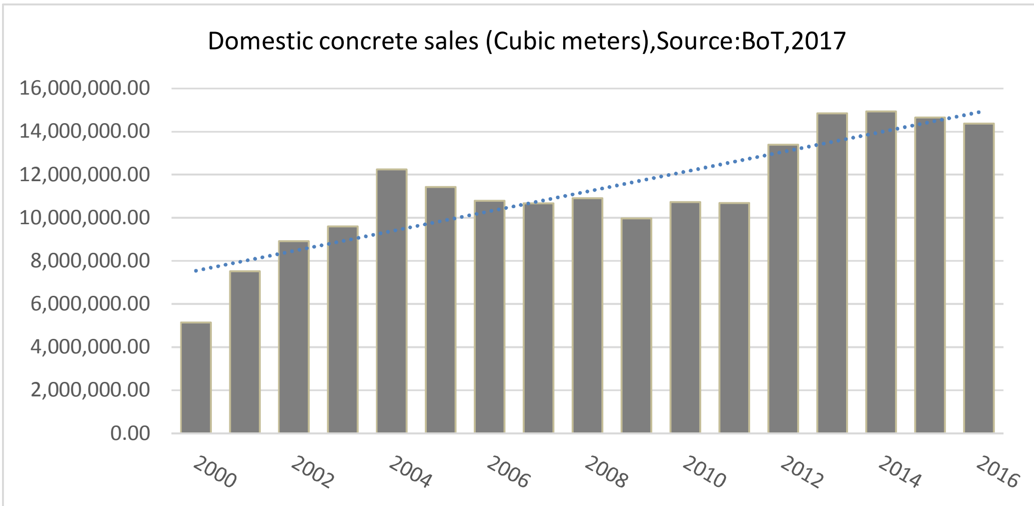
APPENDIX A


Domestic concrete sales (Cubic meters),Source:BoT,2017
16,000,000.00
14,000,000.00
12,000,000.00
10,000,000.00
8,000,000.00
6,000,000.00
4,000,000.00
2,000,000.00
0.00
2000
2002
2004
2006
2008
2010
2012
2014
2016

APPENDIX B

QUESTIONNAIRE

QUESTIONNAIRE FORM

APPLICATION OF SUPPLY CHAIN OPERATIONS REFERENCE (SCOR) MODEL IN READY MIXED CONCRETE SUPPLY CHAIN: A CASE STUDY

Author :Panhavuth Ly, Email:59610054@kmitl.ac.th, Tel:062 9210 245

This form consists of three sections, General Information, Performance metrics, and Environmental metrics. The data filled in this form is solely used for the study purpose only and be kept totally confidential.

Section A: General Information

1. Ready Mixed Concrete Company's Name:……………………………………

2. Respondent's Name:………………………………
3. Department:
   a. Purchase
   b. Production
   c. Logistics/Transportation
   d. Other (Please specify):…………………………………………………
4. Email :…………………………., Tel:..
5. Ready Mixed Concrete Plant Profile:
   a. Number of Batching Plants:……………
   b. Number of Mixing Trucks:……………
   c. Number of Pump Trucks:………………
   d. Average Sale Volume per month:……………..(Cubic meters)

Section B: Performance Metrics

1. Do you have key performance indictors in your business supply chain?
   a. In Sourcing Process: Yes…., No…., Not clear….
   b. In concrete production process: Yes…., No…., Not clear….

c. In concrete transporting or deliver process: Yes…., No…., Not clear….

2. Please do pair-wise comparison of performance metrics below:

2.1. AHP Level 1 criteria pair-wise comparison:

	A - wrt *SCOR Metrics Selection_Deliver Process* - or B?			Equal	How much more?
1	● Reliability(Perfect Order Fulfillment)	or	○ Responsiveness	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	● Reliability(Perfect Order Fulfillment)	or	○ Agility	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	● Reliability(Perfect Order Fulfillment)	or	○ Cost	○ 1	○ 2 ○ 3 ○ 4 ● 5 ○ 6 ○ 7 ○ 8 ○ 9
4	○ Reliability(Perfect Order Fulfillment)	or	● Asset Management	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ● 8 ○ 9
5	○ Responsiveness	or	● Agility	○ 1	○ 2 ○ 3 ● 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
6	● Responsiveness	or	○ Cost	○ 1	● 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
7	○ Responsiveness	or	● Asset Management	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ● 9
8	● Agility	or	○ Cost	○ 1	○ 2 ○ 3 ● 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
9	○ Agility	or	● Asset Management	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ● 9
10	○ Cost	or	● Asset Management	○ 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ● 9

CR = 9.1% OK

2.2. AHP level2 sub criteria pair-wise comparison

2.2.1. Responsiven

Pairwise Comparison AHP priorities

3 pairwise comparisons. Please do the pairwise comparison of all criteria. When completed, click *Check Consistency* to get the priorities.

Which criterion with respect to *AHP priorities* is more important, and how much more on a scale 1 to 9?

	A - Importance - or B?			Equal	How much more?
1	● Order Fulfillment Cycle Time	or	○ Deliver Cycle Time	● 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
2	● Order Fulfillment Cycle Time	or	○ Current logistics order cycle time	● 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9
3	● Deliver Cycle Time	or	○ Current logistics order cycle time	● 1	○ 2 ○ 3 ○ 4 ○ 5 ○ 6 ○ 7 ○ 8 ○ 9

CR = 0% Please start pairwise comparison

Check Consistency

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

2.2.2. Agility

Which criterion with respect to *AHP priorities* is more important, and how much more on a scale 1 to 9?

	A - Importance - or B?		Equal	How much more?
1	Upside Deliver Adaptability	or Downside Deliver Adaptablity	1	2 3 4 5 6 7 8 9
2	Upside Deliver Adaptability	or % of labor used in logistics	1	2 3 4 5 6 7 8 9
3	Upside Deliver Adaptability	or Additional Delivery Volume	1	2 3 4 5 6 7 8 9
4	Upside Deliver Adaptability	or Current Delivery Volume	1	2 3 4 5 6 7 8 9
5	Downside Deliver Adaptablity	or % of labor used in logistics	1	2 3 4 5 6 7 8 9
6	Downside Deliver Adaptablity	or Additional Delivery Volume	1	2 3 4 5 6 7 8 9
7	Downside Deliver Adaptablity	or Current Delivery Volume	1	2 3 4 5 6 7 8 9
8	% of labor used in logistics	or Additional Delivery Volume	1	2 3 4 5 6 7 8 9
9	% of labor used in logistics	or Current Delivery Volume	1	2 3 4 5 6 7 8 9
10	Additional Delivery Volume	or Current Delivery Volume	1	2 3 4 5 6 7 8 9

CR = 0% Please start pairwise comparison

Check Consistency

2.2.3. Costs

Which criterion with respect to *AHP priorities* is more important, and how much more on a scale 1 to 9?

	A - Importance - or B?		Equal	How much more?
1	Cost to Deliver	or Order Management Costs	1	2 3 4 5 6 7 8 9
2	Cost to Deliver	or Order Delivery and/or Install Costs	1	2 3 4 5 6 7 8 9
3	Cost to Deliver	or Risk Mitigation Costs (Deliver)	1	2 3 4 5 6 7 8 9
4	Order Management Costs	or Order Delivery and/or Install Costs	1	2 3 4 5 6 7 8 9
5	Order Management Costs	or Risk Mitigation Costs (Deliver)	1	2 3 4 5 6 7 8 9
6	Order Delivery and/or Install Costs	or Risk Mitigation Costs (Deliver)	1	2 3 4 5 6 7 8 9

2.2.4. Asset Management

Which criterion with respect to *AHP priorities* is more important, and how much more on a scale 1 to 9?

	A - Importance - or B?		Equal	How much more?
1	Cash-To-Cash Cycle Time	or Return on Supply Chain Fixed Assets	1	2 3 4 5 6 7 8 9
2	Cash-To-Cash Cycle Time	or Return on Working Capital	1	2 3 4 5 6 7 8 9
3	Cash-To-Cash Cycle Time	or Inventory Days of Supply-WIP	1	2 3 4 5 6 7 8 9
4	Cash-To-Cash Cycle Time	or Inventory Days of Supply-Finished Goods	1	2 3 4 5 6 7 8 9
5	Return on Supply Chain Fixed Assets	or Return on Working Capital	1	2 3 4 5 6 7 8 9
6	Return on Supply Chain Fixed Assets	or Inventory Days of Supply-WIP	1	2 3 4 5 6 7 8 9
7	Return on Supply Chain Fixed Assets	or Inventory Days of Supply-Finished Goods	1	2 3 4 5 6 7 8 9
8	Return on Working Capital	or Inventory Days of Supply-WIP	1	2 3 4 5 6 7 8 9
9	Return on Working Capital	or Inventory Days of Supply-Finished Goods	1	2 3 4 5 6 7 8 9
10	Inventory Days of Supply-WIP	or Inventory Days of Supply-Finished Goods	1	2 3 4 5 6 7 8 9

CR = 0% Please start pairwise comparison

Check Consistency

Section C: SustainableSCOR performance metrics.

Choose top five metrics that you think is important for in concrete industry.

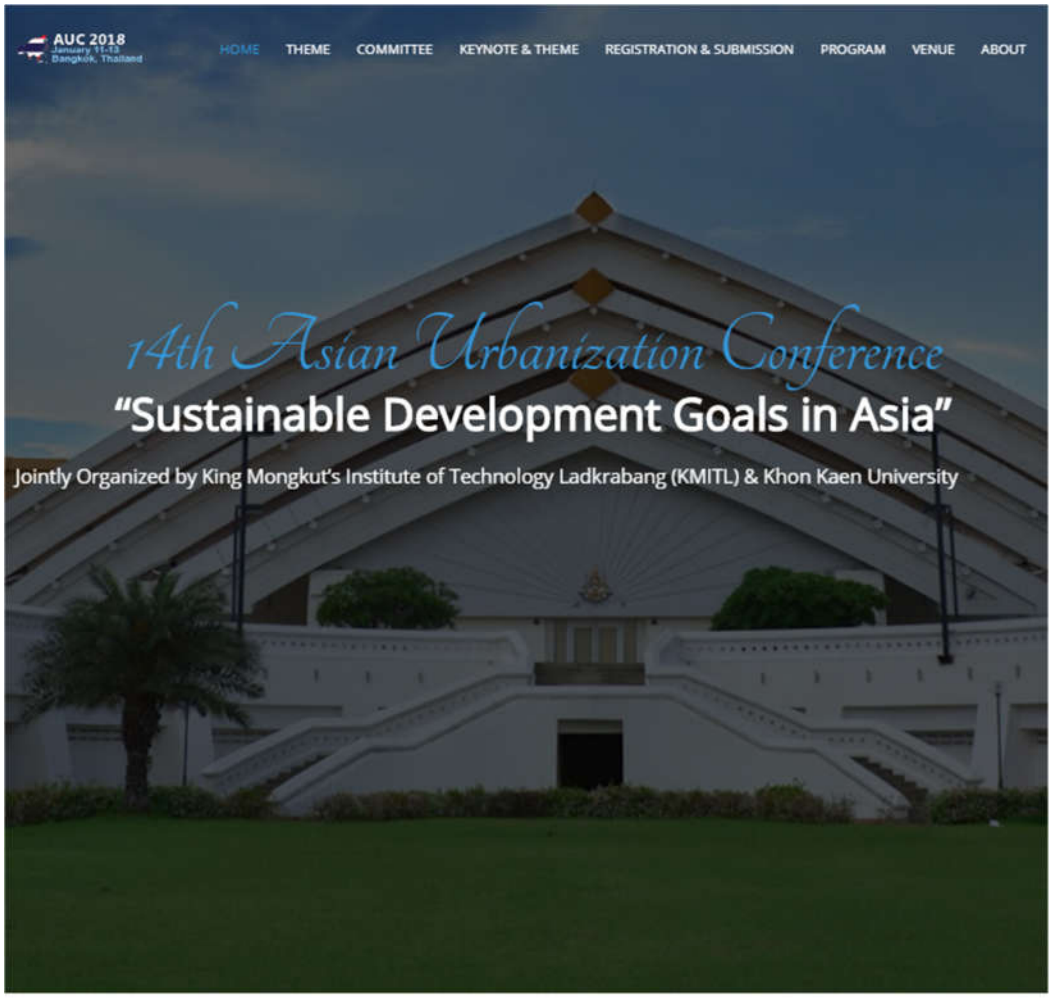
	Sustainable SCOR	Tick to choose
KPI 1	Total Supply Chain Materials Used	
KPI 2	Total Supply Chain Materials Intensity Ratio	
KPI 3	Total Supply Chain Non-Renewable Materials Used	
KPI 4	Total Supply Chain Renewable Materials Used	

KPI 5	Total Supply Chain % of Recycled Input Material Used	
KPI 6	Total Supply Chain % of Reclaimed Products and Their Packaging Materials	
KPI 7	Total Supply Chain Engergy Consumed	
KPI 8	Total Supply Chain Non-Renewable Energy Consumed	
KPI 9	Total Supply Chain Renewable Energy Consumed	
KPI 10	Total Supply Chain Energy Inrensity Ratio	
KPI 11	Total Supply Chain Redution of Engergy Consumption	
KPI 12	Total Supply Chain Water Withdrawn	
KPI 13	Total Supply Chain Water Reused or Recycled	
KPI 14	Total Supply Chain Water Intensity Ratio	
KPI 15	Total Supply Chain Greenhouse Gas (GHG) Emissions	
KPI 16	Total Supply chain GHG Emissions Intensity Ratio	
KPI 17	Rduction of GHG Emissions	
KPI 18	Total Supply Chain Emissions of ozone-depleting substances(ODS)	
KPI 19	Total Supply Chain Nitrogen oxides, sulfur ozides, and other significant air emissions	
KPI 20	Total Supply Chain Air Emissions	
KPI 21	Total Supply Chain Water Discharge	
KPI 22	Total Supply Chain Non-Hazardous Waste	
KPI 23	Total Supply Chain Hazardous Waste	

………………………………..The End of Questionnaire…………………………….

APPENDIX C

14th International Asian Urbanization Conference "Sustainable Development Goals in Asia" at Bangkok, Thailand, January 2018.



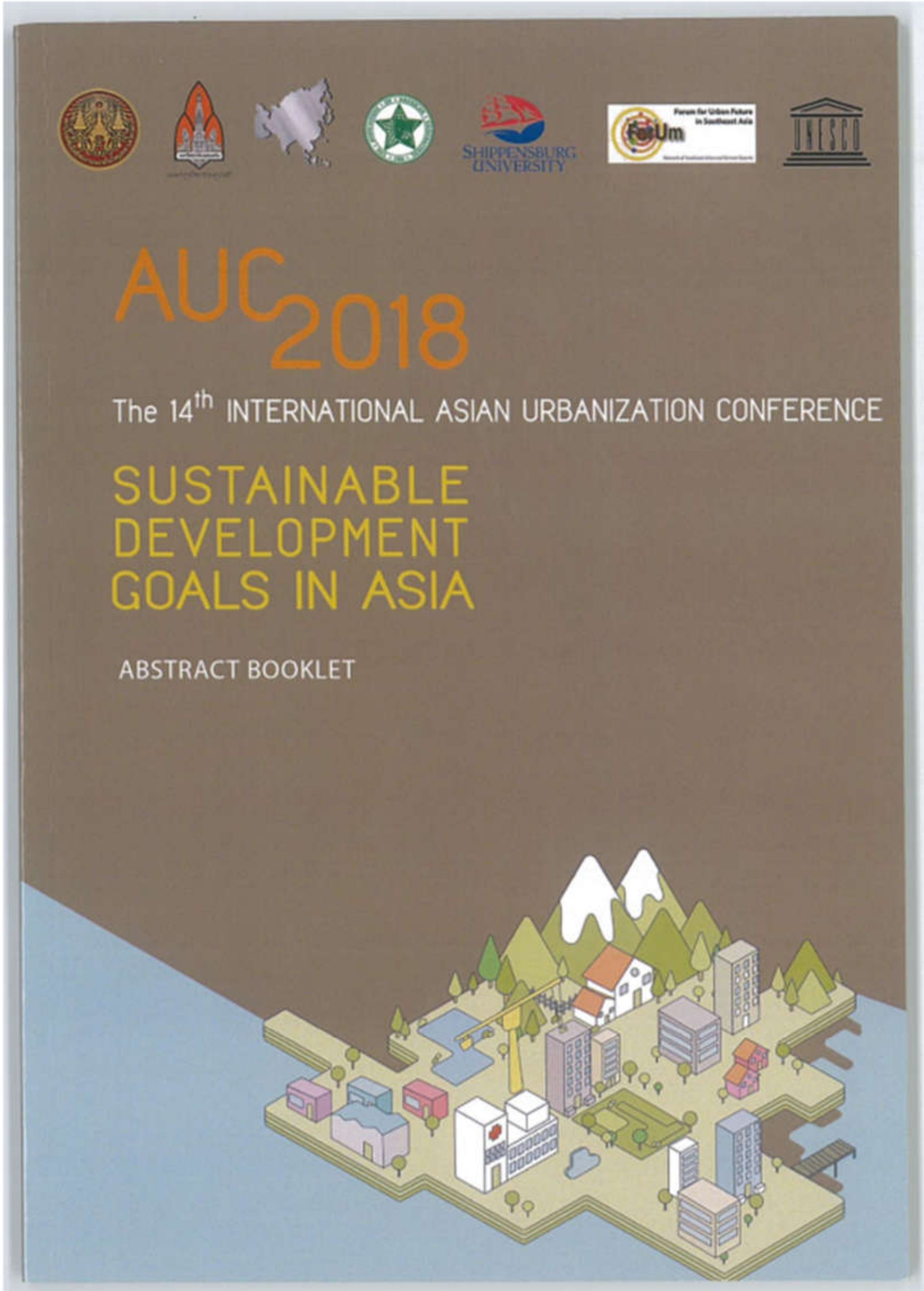
14th Asian Urbanization Conference "Sustainable Development Goals in Asia"

Venue : King Mongkut's Institute of Technology Ladkrabang (KMITL)

Jointly Organized by King Mongkut's Institute of Technology Ladkrabang (KMITL) and Khon Kaen University

Important Dates

- **Paper Abstract due :** September 23, 2017
- **Abstract Acceptance Notification :** September 30, 2017
- **End of Early Bird Registration :** November 19, 2017
- **Full Paper Submission :** November 19, 2017
- **Conference :** January 11-13, 2018


SHIPPENSBURG UNIVERSITY
FatUm
Forum for Urban Future in Southeast Asia
UNESCO
AUC 2018
The 14th INTERNATIONAL ASIAN URBANIZATION CONFERENCE
SUSTAINABLE DEVELOPMENT GOALS IN ASIA
ABSTRACT BOOKLET

Application of GreenSCOR Model to Analyse CO2 Emissions in Ready Mixed Concrete Supply Chains

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Abstract

Supply Chain Operations Reference model(SCOR) has been implemented by organizations for their supply chain improvement and performance. GreenSCOR model, a special application of SCOR model, provides an analytical tool to take environmental impacts of supply chains into account. GreenSCOR systematically captures the impacts in process elements of Source, Make, Deliver, and Return respectively with its metrics. This paper aims to integrate the GreenSCOR model into ready mixed concrete supply chains so that carbon emissions are calculated and visualized in a systematic framework. This study contributes to ready mixed concrete logistics and supply chain managers to monitor and control carbon emissions in their supply chain operations. Importantly, for them to start an initiative mindset in green supply chains, and the effort to reduce carbon emissions that align with government policies and sustainable development goals.

Key Words: GreenSCOR; Carbon Emissions; Ready Mixed Concrete supply chains

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