The Potential of 3PL Involvement in an Asphalt Manufacturing Project

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Abstract

Purpose – This thesis explores and identifies issues considered critical when engaging third-party logistics (3PL) in an asphalt-manufacturing project. The research highlights and discusses those issues including the reliability and maintainability of the equipment used in hauling materials in the project.

Methodology – A comprehensive literature review is carried out on topics relevant to supply chain management and third party logistics involvement in manufacturing projects. Empirical data are collected from a single exploratory case study– Nordic construction company (NCC) Gävle, Sweden. Semi-structured interviews and a brief empirical observation are used in gathering data for this research. Numerical data are analyzed with the application of engineering/statistical theories. Data analyses are performed by relating established theoretical models with empirical findings.

Findings – The findings in this thesis underlined reliability, trust, quality, communication, material haulage, and commitment as critical issues affecting 3PL involvement in the in-house material transportation of an asphalt-manufacturing project. Only Volvo Equipment (brand) is used in the project and its failure rate became very low when exponential distribution theory was applied to check its trustworthiness. The reliability and maintainability of NCC’s delivery equipment showed high significant performance without 3PL involvement. Moreover, the implementation of 3PL within the project has potential benefits, such as cost reduction, and increased employment within the municipality etc. As an environmentally focused project, the standard temperature for asphalt production dropped from conventional 160°C down to 120°C without undermining the quality of asphalt being produced at the plant.

Limitations & Further Research – The generalizability of the concluding results in the study is limited based on selection of only one case-company involving only five persons for data collection and analyses. This study adopts reliability-engineering formulas as instruments used in checking the trustworthiness of the delivery equipment used in the project with focus on the useful period of the machineries. Performing a similar study with a focus on a different period (e.g. wearing-out period of the equipment) would be valuable especially in encouraging Lean Production, Innovation management (RD) in industrial engineering and manufacturing.

Practical Implications – The outlined critical issues can generally be helpful to any manufacturing company that is considering 3PL engagement. It serves as a framework for in-house logistics managers of aggregates transportation within companies that produce asphalt.

Key words- Logistics, third party logistics, reliability engineering, supply chain management.
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Kind regards,

Jude
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Abbreviations

3PL = Third party logistics
HMA = Hot Mix Asphalt
R&D = Research and development
SCM = Supply chain management
PLC = Product life cycle
1. Introduction

1.1 Background

The manufacturing industry is undergoing third party logistic involvement revolution. Day after day, the demand for third-party logistics (3PL) provider by many manufacturing companies around the world becomes increasingly important issue, especially for corporations seeking to improve customer service and cost reduction (Liu and Wang, 2009). This prevalence of third-party logistics involvement in industrial production and services is changing society, organizations and individual behaviors worldwide (Min, 2013; Aguezzoul, 2014). To thrive in this new development, some companies need to be encouraged to follow suit. Especially, since most third-party logistics (3PL) provider today are underused, even though they conceal hidden practices that could lead to important knowledge (Lu et al. 2016). Most leading manufacturing industrial activities in the areas of automotive, steel, including food and beverages are driven by third party logistics (Göl & Çatay, 2007; Kneumeyer & Murphy, 2005). The asphalt manufacturing industry is one of the areas that is currently not adapting to the new trend. There is still little or no evidence of any empirical studies conducted on 3PL involvement in asphalt-manufacturing projects particularly within their in-house material transportation, therefore causing this study to be an exploratory research. The case company in this research is Nordic construction company (NCC) Gävle Sweden, trying to engage 3PL ingenuity as an example of how 3PL could work in practice. NCC is within the leaders of construction industries in Northern Europe. It provides construction services for clients in the areas of buildings for schools and hospitals, individual houses, roads, bridges, sports facilities, power plants and railways. In addition, asphalt becomes part of its production, which provides works for pavements and road constructions for its clients in those projects. Normally, asphalt production engages a batching plant that produces hot mix asphalt (HMA) at 160°C, according to Chandan et al. (2002) who further maintained that the goal of installing a batching plant generally is to ensure an HMA mixture that will confirm specific performance quality.

Nevertheless, a conclusion regarding logistics outsourcing in a study carried out in Finland by Salokivi et al. (2013) was that clients are more satisfied with both the quality of the product and the collaboration with 3PL in the projects. The outlook for future 3PL is interesting (Salokivi et al., 2013). It is believed that the above outcome can be achieved if 3PL is introduced into NCC’s internal logistics, particularly the transportation of materials (stones or aggregates) from blasting site through the crushing machine to the production plant. Literatures used in this study found many rewarding opportunities related to 3PL, including, remunerations from increased productivity, bargained costs, reduced project time due to early 3PL participation, team combination, more opportunities for innovation, improved cost control and constant quality improvements (Gassmann et al., 2010; Ekeskär et al., 2014; GUO et al., 2010). Furthermore, and with the aim of outlining the importance of the revealed gap, both the literatures and empirical findings reveal the growing movement for firms to engage in 3PL activities beyond their boundaries. This movement is quite generous resulting to more than a few critical issues including, cost and risks (Stefansson, 2006; Kang, 2007; Samvedi et al., 2013; Salokivi, et al. 2013). These issues expose and push manufacturing companies to several indecisions while incorporating 3PL into their productions, and on the other hand, often compel them into implementing in-house logistic approaches instead of outsourcing that could reduce the risk of failures, for example on the aspect of ‘delivery equipment’ (Dohi & Yun, 2006; Elsayed, 2012; Hughes & Ferrett, 2015). Therefore, the author deemed it necessary to explore and describe struggles experienced towards incorporating 3PL within the in-house material transportation of an asphalt-manufacturing project.
This thesis is divided as follows; next is the methodology, which shows the applied strategies used in carrying out this study, followed by chapter 3 – literature review, which aided in identifying carefully issues considered critical while trying to engage 3PL concept within the project. It also comprises of empirical findings (chapter 4) drawn from the case company. Chapter 5 consists of the analysis and the discussions part, where the findings are discussed and were compared to the reviewed literatures. The final chapter comprises of conclusion part of the study, limitations of the paper, theoretical and practical contribution and further research.

1.2 Purpose

The main purpose of this thesis is to explore and identify issues considered critical when engaging third-party logistics (3PL) in an asphalt-manufacturing project. The research will highlight and discuss those issues including the reliability and maintenance of the equipment used in hauling materials in the project. The reliability of equipment used in the project is very important in this thesis, given the fact that it helps in defining 3PL’s capabilities in offering sophisticated logistics solutions to manufacturing industries on a local or even global scale. This research aims to answer the following questions:

RQ1: What issues are critical when engaging third party logistics in an asphalt-manufacturing project?

RQ2: How could NCC realize good reliability and maintainability through 3PL on the equipment used in hauling materials in an asphalt-manufacturing project?

2. Methodology

This section explains the research method applied in this study, which follows industrial engineering research approach. In addition, these strategies are individually and intertwinely discussed to gain profound knowledge of the quality of the research and the impending limitations. The single case company-NCC is introduced at the final part.

2.1 Research Strategy

Qualitative or quantitative methodologies are often the two most common methodological approaches applied in scientific researches. Qualitative research is defined as a “research process that uses inductive data analysis to learn about the meaning that participants hold about a problem or issue by identifying patterns or themes” (Lewis, 2015). Qualitative research approach takes into consideration interpretive actions, including multiple methods and strategies used in many dispersed fields of academics (Denzin and Lincoln, 2011 p.5). Denzin and Lincoln (2011) stipulate that qualitative approach counts more on why and how than merely investigating what, where and when. Furthermore, qualitative method focuses more on the depth of data rather than numbers when collecting information and analyzing them (Murry, 2008). The main objective of qualitative research seems to be explanation and focus on effects in specific cases (Beverland and Lindgreen, 2010). Quantitative methodology on the other hand involves data collection and analysis using accurate measurement for phenomena, which repeatedly uses the application of statistical analysis (e.g. Efendigi et al., 2008). Quantitative research is known also for quantifying relationships between variables.
Both qualitative and quantitative researches have been on ‘the paradigm wars’ (Bryman, 2006 p.16).

The alternative approach to the aforementioned research methodologies is the integration of both qualitative and quantitative approaches commonly known as mixed method research but sometimes referred to as multi-strategy research method, which is increasingly becoming popular (Robson and McCartan, 2016 p. 30). Both qualitative and quantitative methodologies have been combined in many cases (Bryman, 2006; Johnson et al., 2007; Day et al., 2008). The combination as a distinctive research approach is seen in its own pattern deserving some comparisons (Bryman, 2006 p. 97). Figure 1 shows basic characteristic among the three methodological approaches according to Creswell (2013).

<table>
<thead>
<tr>
<th>Quantitative</th>
<th>Qualitative</th>
<th>Mixed Methods</th>
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<tbody>
<tr>
<td>Experimental designs</td>
<td>Narrative research</td>
<td>Convergent</td>
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<tr>
<td>Nonexperimental designs e.g. surveys</td>
<td>Phenomenology</td>
<td>Explanatory sequential</td>
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<td></td>
<td>Grounded theory</td>
<td>Transformative, embedded or multiphase</td>
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<td>Ethnographies</td>
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Figure 1: source: characteristics of methodologies (Creswell, 2013)

However, diverse ways exist within industrial engineering research under which researches can be performed. The choice according to Stake (2005) and Yin (2009) ranges from experimental, analytical, surveying, and historical to case study selections. They all have complementary strengths and weaknesses (Yin 2011). For example, case study research is perceived as “an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin, 2013). This perception captures the fact that case study is intended and contrasting the shallow and generalizing methods, thus providing some level of detailed understanding. Many scientists still believe that case studies are only suitable for the exploratory research (Yin, 2009 p. 6). Exploration and explanation of complex issues for example makes the case study research a considerable robust research method especially when a holistic, detailed research is required (Zainal, 2007). However, there have been existing comparisons between single-case study and multiple-case studies (Zainal, 2007; Yin, 2009). While single case study analysis can through the application of qualitative and or quantitative research methods provide a sound, observably rich and holistic account of unambiguous phenomena (Yin, 2009) the multiple-case design embraces real-life events that show numerous sources of evidence through repetition rather than sampling logic, according to Zainal (2007). Zainal (2007) kept arguing that in some case studies, an in-depth extended examination of a single case or event is used.

Yinan, et al (2014) designed a research structure and empirically tested some hypothesis through analysis of the data collected from a High Performance Manufacturing (HPM) project using quantitative approach while Kim et al (2008) applied a qualitative methodological strategy in third-party logistics systems using a case analysis. Literature review techniques were applied virtually on those two cases. Given the above circumstances and considering the fact that research questions have been developed in this thesis, case study is considered as the most appropriate method in this study. The aim investigates the effects of inaugurating third party logistics in a manufacturing project as well as investigating what the manufacturing companies seek by engaging in 3PL, which turns this research into an exploratory single-case study.
There have been many critics towards case study methods due to its weak wholesomeness as an exploratory instrument. Consequently, designing the project using case studies becomes extremely an important phenomenon (Zainal, 2007 p. 2). Zainal (2007) has mentioned for example, the options researchers have over adopting either a single case or a multiple case design depending on the issue in question, which is also in line with Yin (2013) postulation. It is important also to have a research design (Yin, 2013 p. 3). The overall reason for a research design anchors around the study of a set of critical industrial events (Alberti, 2006 p. 476). The author designed three phases towards realizing a quality composition in this study since no formula is still in existence towards research design approach rather than huge dependency on the research questions (Yin, 2013 p. 4). The author chose the research strategy in order to design, collect, and analyze data fairly (Yin, 2013 p. 5).

2.1.1 Design Phase

A logical case study research has been designed (Yin, 2011 p.75) which followed development of a theoretical framework using a secondary data source (Bryman, 2006; Yin, 2013). Figure 2 shows the flowchart of the methodological phases.

![Methodological Phases Diagram](image-url)
Issues that are considered critical in engaging third party logistics in an asphalt-manufacturing project are clearly spelt out later in this study by reviewing these literatures. The arguable feature of this single case design following Zainal (2007) postulation is in its lack of ability to provide a generalizing conclusion since it lacks comparisons and again the subject (3PL involvement within the in-house department of an asphalt-manufacturing project) is very rare in occurrence.

2.1.2 Data Collection

The secondary data are sourced mainly from journals, articles, books, and industrial reports using many scholarly databases through the University of Gavle’s internet service. Virtually the search gap did not exceed 10 years old literatures, which helps the author in grabbing latest information about third party logistics in the manufacturing industry. In addition, the author received through the company’s department, some internal documents relating to the delivery equipment, quality control, and material transportation modes. The author visited the production site 3 times. Data is collected by means of interviewing five managers within the department using a semi-structured interviews with open-ended questions, which according to Yin (2013) offer the most important means of obtaining information. Researchers are often recommended to use open-ended question such as in Sharples et al. (2015). Such recommendation in this case helped the author in getting unstructured and expounded responses from the managers.

Figure 3 illustrates the entire length of the interview process. The interviews took around 60 minutes and were independently conducted same day on the five managers. ‘Focused interview technique’ (Yin, 2011 p.179; Yin, 2013) are employed which helped in understanding both the managers’ general view on the critical issues relating third party logistics involvement in the project and material haulage issues within the company’s production department. Few data are generated quantitatively since the boundaries between the phenomenon and context are not so clear (Yin, 2013 p.4). The interviews are recorded to enable the researcher recollect, find wordings and references that clarify unclear sections (Yin, 2011). Despite the fact the interviews are recorded and involved only one researcher, the interviews are conducted in such a way that same researcher ask questions as well as writes down some of the interviewee’s key issues/responses on pieces of papers. This approach sav-
es time, which allows the researcher to use the notes instead of pining ears down and back to every recorded interview during result/analysis period of the Thesis. The audio tape is broken down and labelled in parts, which enables the author to listen once again to areas and sections that require more clarifications (Carlson, 2010).

Firstly, at the start of the interview, the author introduced himself and then the project. The importance of third party logistics is presented and discussed. The author shares his personal knowledge and experience in asphalt production, which in reality is among the motivations for this research (Jacob and Furgerson, 2012). The interviewees expressed no discomfort and embraced the idea as wonderful and welcoming. Then the questions relating to issues affecting material haulage, reliability of the equipment and 3PL implementation in the project are launched. Two of the interview questions are ‘in-depth’ (Yin, 2009) which for the purpose of research question helps the author in grasping a general knowledge about business nature of the firms manufacturing department. That also logically helps the author in exploring and identifying the possibility of third-party logistics involvement in the project. Three of the questions are ‘focused interviews’ (Yin, 2011). That defines many principles surrounding material haulage, which is among the core business of third party logistic firms (Kim et al. 2008). Krueger and Casey (2014) have advocated involving only few people when studding a focus group. In total, the interviews consist of only five managers and the questions are introduced carefully with “open questions” (Krueger and Casey, 2014).

Cheryl (2010) has encouraged that construction of research questions should be rooted on reviewed literatures, hence these questions circled around general perception of 3PL and some critical issues relating to material transportation in several projects (e.g. Knemeyer et al. 2005; Zwikael & Globerson, 2006; Göl & Catay, 2007; Kayakutlu & Buyukozkan, 2011; Leuschner et al. 2014; Ekeskär et al. 2014). In order to relate the impact of the critical issues to some theories, follow up questions are asked to the five professionals regarding their inputs and suggestions about engaging 3PL in the project. The final question in the interviews aimed at the reliability of the mode of material haulage (equipment that transports the materials) in which case if the company refuses to embrace 3PL implementation assuming this Thesis concludes consequently. Then a recommendation can be given base on latest reliability survey study on vehicles’ performances (lifecycle of equipment) (Stark, 2015) especially those vehicles that handle rugged terrains. Additionally, the time between researcher’s introduction of himself and the interviewee’s emotion/reactions took longer than the time between the interview period and the conclusion as seen in figure 2, probably because the researcher is offered cups of coffee on different intervals. The research questions can be found on Appendix 1.

2.1.3 Data analysis

The unit of analysis of this thesis is the asphalt department of Nordic Construction Company in Gavle Sweden. The analysis of data is performed by relating and cross-examination of the empirical findings to the developed theoretical background. Key issues that constantly surfaced in the empirical findings are analyzed and underlined as being critical in an asphalt-manufacturing project and the author through a repeated study of the jotted scripts and the audio tape identified those issues, including how they fitted within the developing subject (3PL involvement in asphalt project) as recommended by Thomas (2006 p.239). By relating empirical findings to theories about 3PL, different themes were captioned to enable in interpreting and describing the significance of the findings. Parts of the data came in numerical forms and were analyzed using industrial engineering theories. Part of the data analyses are performed also exclusively on the reliability of the equipment use within the asphalt manufacturing project in order to support the discussion and the analysis sections.
That helps in defining whether 3PL involvement in the project would produce a different result based on the equipment’s reliability. That also helped in analyzing and identifying 3PL’s positive and negative effects on asphalt manufacturing project. With the above approach, subjectivity is reduced (Laine and Vaara, 2007). After the empirically gathered possible effects of third party logistics involvement in the project are compared to theories and analyzed, conclusion is then drawn on NCC willingness to embrace 3PL concept. Eisenhardt et al. (2007) have urged researchers to follow the above steps in drawing conclusions.

Most of the empirical part of the data were expansively gathered but compressed into a summarized format. Some of the interviewee’s responses (with short words) are quoted directly during analysis. According to Laine and Vaara (2007) researchers can review collected data independently and strategically test the compatibility of the findings as another step to reduce subjectivity. The researcher also reviewed all interviews independently. Lastly, the empirical cross-sectional analysis is matched with the theoretical framework to identify positive and negative effects of 3PL for each of the critical issues. Thereafter, a satisfactory foundation is formed to conclude on the critical issues affecting 3PL involvement in an asphalt-manufacturing project.

2.2 Quality assessment

For the empirical data used and analyzed in this research to gain weight, Yin (2009, pp. 41-45) has propounded four assessments as yardsticks to be used in measuring a case study research. The assessments include construct validity, internal validity, external validity, and reliability. Each of these yardsticks is discussed independently in the next section. An interesting way of rising above the aforementioned situation according to Yin (2009, p. 15) is by triangulating the study with other methods including statistical analysis, literature review technique etc. to confirm logically the validity of the process while theory is being developed in the research design to deal with subjective issues in the case study (Yin 2009, p. 35). The method however is used later in the research in analyzing the empirical findings while relating them to the identified theories, which the author perceives as a big strength.

**Construct validity**

Since construct validity deals with finding the applicable measures for the concepts that are being studied in case studies, it has been associated with some difficulties when it comes to dealing with applications of the measures, and the measure often are biased due to the findings are based on personal judgement (Yin, 2009 p.41). Therefore, the questions that were asked during data collection have direct link to the research purpose. In addition, a secondary data source was added into the equation following hardcopies of internal management control memos received by the author from the interviewees. These additional data became necessary and were used in understanding the firm’s specific management approaches, which helped to obtain a realistic view of the company during the data analysis. Some of the data from interviews are linked to data from secondary data particularly in the areas of equipment’s reliability, failure rates of the equipment, etc. in order to check the data credibility (Smith, 2011). However, one limitation within the collected data is that some interviewees’ work experiences have not covered a long period for them to observe failure rate of the equipment, which prompted more information from the quality control manager as an alternative leeway. Thus, to increase construct validity, the author has individually analyzed each of the in-depth interviews and conclusions were reached based on industrial scientific approach and on personal judgement.
**Internal validity**

The author in this case study considers internal validity as formation of causal relationships in certain ways that demonstrates how certain conditions lead to other conditions, differentiated from false relationships (Yin, 2009). Thus, the data collected from interviews took the pattern of relating them to more than one research, between jotted notes and the recorded audio tape commonly referred to as “multiple sources of evidence” (Yin, 2009; Denzin & Lincoln, 2011; Flick, 2009). Such approach is used in increasing the internal validity in this research following also the exclusive interviews performed on the head of the department (HOD) asphalt production, the quality control manager (QCM), transportation manager (TM) and 2 Operation Manager (OPM) whose roles can be site engineers, machine operations. The pattern also increases the internal validity for this study to some extent since internal validity refers to possibilities of ‘good matches between researchers’ observations and the theoretical ideas’ (Yin, 2013). The above pattern coincides with the findings and ‘if patterns coincide, the results can help a case study to strengthen its internal validity’ (Yin, 2009, p. 136). Another important tactic for achieving a strong internal validity is to have a draft of the report (written down data) handed over to a key informant for validation. One of the interviewees (QCM) became a key informant that is handed in a draft of the completed interview in order to confirm the coherence. While factoring these requirements into this study, the researcher has explained appropriately the causal relationship between the different issues, and their overall impact on 3PL involvement in the project. To comply with other requirements, the theoretical framework helped in underlining in detail those issues as being critical with reference to scholarly literature. Considering the above-stipulated steps, it is believed that a satisfactory level of internal validity is attained.

**External validity**

The degrees to which this study’s findings can be generalized across broader settings constitute an external validity (Yin, 2009). Yin (2009) argues that the general problem with case studies is the problem of external validity. Some exponents (e.g. Yin, 2009; Flick, 2009) characteristically say that single case studies are lacking for generalization. The author is fully aware of that fact and encourages future research to prove the possibility of the study having external validity by researching whether the conclusions hold true for other industries within the asphalt manufacturing business. Hence, the author states that the generalization of the main findings is low, as the research design of the study is not suitable for generalization across broader settings. Thus, only one firm (NCC) situating in Gavle Sweden is chosen to address the influence of third party logistics involvement in an asphalt manufacturing company. The author believes that there could be generalizability if considering only the positive influence of 3PL adoptions by many other firms. 3PL is widely applied in many firms across the globe especially in supply chain management. In addition, 3PL is a fundamental model in many companies. Furthermore, few of the data in this qualitative research are gathered in numerical forms. These data can only be analyzed using engineering formulas but still cannot be used to make statistical generalizations because in statistical generalizations, an inference is made about a population based on empirical evidence that has been collected from a sample of a larger target population (Yin, 2009 p.44). While the generalizations that may be made from case study are analytical in nature (Yin, 2009 p.43) it would be invalid to link the case study with statistical generalizations since the case is not “sampling units” and is not chosen for this purpose. It is important to factor into consideration that qualitative and quantitative approaches can be mixed in case study analysis (Bryman, 2006 p.97) and that is partially applied in this case.
Reliability

A critical challenge when presenting a study is to provide the readers with reliability and clarity. The author perceives reliability referring to the degree to which a study can be redone (Yin, 2009) as very crucial. It is ensured by the author that the presented research procedures are described in details in order to enable future researchers on 3PL involvement in internal material haulage of an asphalt project to carry out the same study over again and to arrive possibly at the same findings or conclusions. This is done by applying Flick (2009 p.386) suggestions which includes, to engage in interview training, use of interview guides or conduct test interviews, hence the researcher has some knowledge in scientific methods for industrial engineering researches and has practiced such exercises severally.

The process and methods used in this research study is documented properly, it is believed that reliability, and clarity will provide future research repetition with adequate first-rate material. The researcher believed what he saw during the 3-times site visits at the production plant likewise believed the information obtained from the interviewees during the interview, which is another way of increasing this study’s reliability according to Flick (2009, p.387). Through discussions with the quality control manager (QCM) and afterwards transliterating of the interviews, the researcher shared his views and interpretations with the QCM in order to minimize the prejudice and ensure that the interview result is coherence (Yin, 2011 p.141).

2.3 Ethics and societal aspects of the research

The ethical aspect of a study research deals with norms for conduct that distinguish between acceptable and unacceptable behavior while data is being collected during a research (Resnik, 2011; Yin, 2011 p.39). In other to rise above some ethical conflicts, the author developed some personal relationships with the participants prior to the data collection date, which according to Sanjari et al. (2014 p.3) may be inevitable. This is done through a face-to-face meeting before the real interview date. The approach is time consuming but was followed in order to develop both trust and friendship and to share also confidential information and internal document between the two parties. Therefore, the researcher earnestly considered the potential impact he may have on the interviewees likewise the other way around, since ‘qualitative researchers are guests in the private spaces of the world and their manners should be good and their code of ethics strict’ (Stake, 2005, p.459).

The societal aspect of this study could be viewed from the perspective that after developing better understanding on how to adapt the competences of 3PL into the company’s business, the company could create competitive advantage and differentiate herself from their competitors. Other asphalt-manufacturing firms in and outside Sweden could emulate 3PL incorporation into their internal logistic. This is because with 3PL as a strategic tool, risks in supply chain management can be quantified and reduced and cost reduction strategy introduced and implemented (Samvedi, et al. 2013).

2.4 Case Company

This section introduced briefly Nordic construction company (NCC). Emphases are placed on sales, environment, and the firm’s material (stones or aggregates) transportation.

Nordic construction company (NCC)

Nordic construction company (NCC) was chosen in this case because of its leading role position in Northern European construction industries. The firm provides construction services in the areas of buildings for schools and hospitals, houses, roads, bridges, sports facilities, power plants and railways. The company is also located in Gavle, Sweden, which is
in a good proximity from the University of Gävle’s campus. In addition, it produces hot mix asphalt (HMA) that provides works for pavements and road constructions for its clients in those projects. The company had sales of SEK 62 billion in 2015 with approximately 18,000 employees (NCC, 2015). NCC also engages in production of ‘green Asphalt’ (NCC, 2015) which is considered as one of many environmentally friendly products the company has developed in recent years. Through innovation in developing production and blending methods, the company manages to lower the temperature of hot asphalt while maintaining quality, resulting to the environmental benefits of reduced carbon dioxide and nitrogen oxide emissions.

A crucial part within NCC’s operations is the provision of logistics for transportation of the materials (crushed stones) or aggregates (see appendix 2) from the blasting site to the production plant. The delivery process for these aggregates including assembling them before dropping and engaging them into production through ‘feed bin to belt conveyor’ (Chandan et al. 2002) is quite a complex structure. Whereas the logistics management strategies use within the plant (premises) is handled 100% by the company’s in-house logistic arrangement, this study’s focus is on third party logistic involvement within the production plant in Gävle Sweden. Figure 4 shows the complex structure of the aggregates supplies from stage 1, stage 2, and stage 3 to stage 4. The arrows show different material transportation directions.

![Figure 4: complex structure NCC aggregates supplies](image)

### 3. Literature Review

This chapter reviews the selected theoretical frameworks and the considered critical issues related to the thesis. It is divided into different sections: SCM, Outsourcing, 3PL, Equipment Reliability.
Logistics issues

Logistics is defined as ‘the general management of how resources are acquired, stored, and transported to their final destination - Logistics management involves identifying prospective distributors, suppliers, and determining their effectiveness and accessibility. The strength of any form of logistics management is to establish a link with suitable firms or let the logistics be handled by own business if the cost is more effective’ (Investopedia, 2016).

3.1 Supply chain Management issues

The pursuit for a consensus definition for supply chain management (SCM) is still rolling (Gibson et al. 2005; Fahimnia et al. 2015; Christopher, 2016). The latest definition by Christopher (2016) refers to SCM as ‘the management of upstream and downstream relationships with suppliers and customers in order to deliver superior customer value at less cost to the supply chain as a whole’. While the above definition of SCM focuses on ‘cost reduction’, other SCM characterizations have their focus on the environment (Eisenhardt & Graebner, 2007; Lieb & Lieb, 2010). Another focus of supply chain activities is on “product development, sourcing, production, and logistics, as well as the information systems needed to coordinate activities” (Odoom, 2012). GUO et al. (2010) on the other hand had their focus on the process of a supply chain’s response to market, which they believe should be extended more to market direction, new product’s R&D and some necessary adjustments. A whole process according to GUO et al. (2010) is that supply chain response to a market-change ought to be from researching a new product based on a new market demand to delivering the final product to consumers. The process is further divided into three phases comprising of; a) researching and developing a new product, b) adjusting or rebuilding supply chain for producing the new product and c) operating and managing this new supply chain.

Nevertheless, the concept of SCM in recent years is increasingly becoming connected, in the sense that decisions taken by one organization in a supply chain affect directly the operation of other corporations. This implies that any disruption caused at one level can be transmitted right away to other levels consequently resulting in huge impacts. Such impacts have led to growing interests in the area of supply chain management as evidenced in the number of industrial case studies, literature reviews, and study reports devoted to the topic (e.g. Bhatti, et al. 2010; Yang & Fong, 2013; Leuschner, et al. 2014). Based on the above context, supply chain management is then the vigorous management of supply chain activities to maximize customer assessment and achieve a competitive benefit, which embodies an intentional effort on the part of the supply chain companies to develop and run supply chains in the most effective and efficient acceptable ways (Potti and Saurav, 2016). The establishments that make up the supply chain are connected together strongly by virtue of physical flows and information flows (Kachru, 2009). Physical flows according to Kachru (2009) involve the transformation, movement, and storage of goods and materials, which are mostly the visible part of the supply chain. Information flows on the other hand are an ‘important determinant of firms’ boundaries’ (Massa and Rehman, 2008) which simply means fast communications skills.

Many authors according to Felea and Albastroiu (2013) have assigned stability and growth of SCM to the historic development of the logistics function and a number of them consider that SCM and logistics are substitute expressions. Waters (2007, p.38) for example states “Logistics or supply chain management is the function liable for the transport and storage of materials on their travel from original suppliers, through intermediary operations, and to the last customers.” Even though supply chain management comprises some of logistics management contents, but then there is still difference between the concept of supply chain
management and the traditional view of logistics. Logistics operations for example take into account the management functions responsible for all movement and organizing of materials within the boundaries of a single organization while SCM takes a wide-ranging view of movement through every interrelated organization that forms the supply chain.

3.2 Outsourcing issues

Outsourcing means ‘hiring a third party to perform the needs of an operation’ (Smith, 2012). Logistics is seen to be one of the supply chain activities that are steadily outsourced, that became evident by the constant growth of the third-party logistics (3PL) industry around the world (Min, 2013). The trend is becoming more common in many industries for services that usually been viewed as core to managing a business. Not long ago, Min (2013, p.133) advocated that the just concluded global recession had forced many firms to think back on their business strategic idea. It seems the idea followed Friedman (1970) postulation of sharing responsibilities and increasing profits. However, this change in strategic thinking according to Min (2013 p.141) includes the review of firm’s business strategies that may not certainly enhance or add the higher value to the supply chain process and may not bring a higher possible profit from firms’ distributed resources. The reasons why companies decided to outsource or not to outsource their logistics are so diverse (Min, 2013, p.144). Many theories have been propounded and mentioned by various authors (e.g. Liou et al. 2010; Chou et al. 2009; Bengtsson et al. 2009; Min, 2013; Salokivi et al. 2013) relating to why firms outsource their logistics functions. Cost cutting and focus on core business activities are among those frequently mentioned. The study by Salokivi et al. (2013) for example explored the various aspects of logistics outsourcing in companies operating in Finland with results showing the analysis of outsourcing motives within the sample. Amazingly, both the manufacturing and the trading companies mentioned flexibility as the number-one drive for logistics outsourcing (Salokivi et al. 2013 p.392). Also mentioned as among the reasons for outsourcing among the 299 companies is the ‘fear of losing control of the operations’ (Salokivi, et al. 2013 p.393).

To shade more lights into the concept of outsourcing, Chou et al. (2009) have stressed on the needs to perform proper risk analysis and quality control process for a successful outsourcing project within the information technology industry. In their remarks, it is proposed that in order to be well informed for corporate information system outsourcing, a firm must recognize current market situation, its attractiveness, and economic location (Chou et al. 2009 p.1039). Indicated also by Chou et al. (2009) was the need for identification of outsourcing success factors, which can be used to serve as the directives for strategic outsourcing planning. Nevertheless, whether or not an outsourcing contract is established between the 3PL and the business owner historically both parties according to Kim et al. (2008 p.522) experience competition among their individual companies because of dominant business strategy on how to gain the largest share of market space. That becomes an interesting issue on outsourcing.

3.2.1 Problems and Criticism of Outsourcing

In the face of strong arguments for outsourcing research, previous studies according to Bengtsson et al. (2009 p.35) on outsourcing outcomes have demonstrated few or conflicting results concerning the impacts of outsourcing on performance. By contrasting outsourcing and integration strategies in manufacturing using both a developed theoretic frameworks and hypotheses, Bengtsson et al. (2009) acknowledged that outsourcing has become a common
strategic tool in many Western manufacturing firms in many years. Thus, in their study in analyzing how two different outsourcing manufacturing tactics have dealt with plant performance and innovation capability in view of organizational integration of design and manufacturing in addition to product complexity based on a survey of 267 engineering firms, Bengtsson et al. (2009) identified the following:

a) The correlation analysis showed that early supplier involvement in product development is more beneficial for firms applying an innovation outsourcing strategy than for firms applying low-cost outsourcing, based on combined effects of outsourcing and integration.

b) With an insignificant difference, firms that applied an innovation-oriented outsourcing have a lower cost reduction capability than low-cost-oriented firms.

c) By weighing the combined effects of outsourcing manufacturing and integration, the study underlined that managing crossing point is key to the successful management of some outsourcing problems.

Outside the above problems and criticism leveled by Bengtsson et al. (2009) in their research, evaluating outsourcing choices requires keeping in mind that there are advantages and disadvantages for outsourcing. For example, the livelihood of any manufacturing business is the information that keeps it running, and if some files or any other confidential information is to be communicated to the outsourcing company, there can be a risk that the privacy may be exposed (Samvedi, et al. 2013). Therefore, careful evaluation of the outsourcing company becomes imperative while making sure that data is protected and the contract (between the outsourcer and 3PL) has a penalty clause in case of any incident occurrence. On the other hand, among the advantages of outsourcing is that ‘the impact of external integration on outsourcing outcome is stronger when product and manufacturing complexity is high’ (Bengtsson et al., 2009 p.38). Hence, the result of Bengtsson et al. (2009) hypothesis showed that facilitating external integration requires internal integration, in the case of manufacturing and product development relationship, which serves the purpose of establishing an efficient development process. Furthermore, the findings of Bengtsson et al. (2009) study confirmed and reformulated the conclusions of Marshall, McIvor and Lamming (2007) according to Bengtsson et al. (2009) in the sense that part of the results disclosed that supplier collaboration is beneficial especially in the case of innovation-based outsourcing.

Nevertheless, if outsourcing disadvantages outweigh the advantages of outsourcing, then outsourcing operations should be avoided. Belso-Martinez (2010) has equally evidenced that while describing outsourcers in advanced industries with competitive problems for the most part in southern Europe. Despite the fact that multiple empirical studies support the positive relationships in outsourcing (Belso-Martinez, 2010 p.3061) the qualitative result revealed that firms with higher investments in product and process innovation are more predisposed to contract-out manufacturing. While referencing Barney (1999) in order to validate the findings that were assumed to be consistent with many scientific theories, Belso-Martinez (2010 p.3068) sees firm as an exposed system where other firms develop relations with domestic and foreign independent organizations just to access priceless technologies or knowledge. That implies that the degree and extent of organizations’ openness and control (Bengtsson et al., 2009) is a huge outsourcing challenge which arguably has outsourcing consequences.

Outsourcing has collaborative issues, many articles have emphasized. Of course, new ideas (through collaboration) with other allies are always uncomfortable and ill designed at first. In other words, nothing works faster than snatching ideas off others including helpful individuals. This back-and-forth exchange of ideas through outsourcing is critical in helping to form ideas into something more solid, reasonable, and achievable. Then outsourcing should additionally be ready to face the trickier challenges and criticisms, for example from line management and others within the industry. In contrast, it is not possible also to outsource
some activities through collaboration because the same employees and machineries are required for the same core business (Tidd and Bessant, 2014). Another challenge for outsourcing can be classified under firms’ pursuits to be the leader within the concept of “Continuous Improvement” (Dabhilkar et al., 2007). Primarily, because the nature of the firm’s businesses, which is the purpose of existence and the set goals, force them to have assurances to their consumers and to ensure stability in supply in order to keep their certificates and maintain their brands by which they realize continuing success. Outsourcing therefore, becomes a key issue in this practice and implies implementation of some risky feature for example “open innovation” (Bengtsson, et al. 2015) which is believed to be a very risky approach that can lead to identity theft or lost in total quality management of products. As seen in some literatures (e.g. Samvedi et al., 2013; Osorio et al., 2016), identification of logistic solutions using statistical methods which is time consuming also pose some problems in outsourcing.

3.3 Third Party Logistics

There is no watertight definition for third party logistic. Many authors kept criticizing in favor and against varied forms of definitions (Marasco, 2008). Yet, they all have one thing in common ‘our business organization cannot deliver the project/service single handedly’. 3PL is seen by many in the public sector as a way of moving away from argumentative relationships in manufacturing projects and approach a more collaborative method of handling projects (Stefansson, 2006). Stefansson (2006) concluded that the drivers for public firms at least in the Scandinavian countries adopted 3PL because they were told to do so by articles and reports while recognizing that the distribution-structure gave rise to considerable savings for decreased inventories, decrease in warehouse operation costs, increased delivery performance and decrease in average lead-time. Prompt delivery is one of the critical success factors of 3PL and one of the reasons why 3PL is a concept of great importance to the industry. Subramanian et al. (2014) empirically tested the relationship between the 3PL sizes and customer satisfaction on a young population with the support of structural equation modeling (SEM) as dominant customer satisfaction factors. The result showed that the quality of service on the part of 3PL has huge impact on customer satisfaction and both reliability and responsiveness significantly influence customer satisfaction as in meeting customers’ requirements.

Again based on a survey conducted on 40 chief executive officers (CEOs) of various biggest 3PL operating in the European, Asia-Pacific, and North American 3PL markets, Lieb and Lieb (2010) findings indicated that virtually all of the companies involved made extensive commitments to environmental sustainability goals during the past several years. They launched an expansive range of correlated projects that had quite positive impacts on those companies despite the kick-in by recession. None of the scaled 3PL firms reversed their commitment to those goals. The 3PL system is designed to manage huge, complex, and customized projects with lengthy duration (Binh, 2016; Potti & Saurav, 2016). These kinds of projects are becoming more common in today’s advanced industries. According to operation cost economics, the cost of using 3PL in small, unique, and less complex projects is higher when compared to the returns. The projects size and complexity have led the conventional delivery methods to fail in satisfying clients’ standards. Because of these, 3PL started to evolve and with the purpose of achieving a good project, for example, Wolff (2014) stresses on the importance of all stakeholders (top – down) to be engaged in the process of changing the approach. Manufacturing projects are all different in their individual ways anyway.

When it comes to choosing the appropriate material (goods) delivery form, clients need to evaluate the most appropriate strategy that suits their project’s requirements. What is
understood to be the main factor when it comes to selecting an appropriate 3PL method is suggested to be the risks (Samvedi et al., 2013). This is one of the reasons why 3PL is important to be discussed. 3PL has different ways of allocating risks, increasing quality and reducing production lead-time than most other dominant forms. The customer and the service provider share the risk to a larger degree than in an average project approaches. If a new SCM system for example is to be accepted by an industry, the clients have to know how to use it otherwise, companies are beginning to apply the technique of external collaboration (3PL) to manage product variety and customization (Yinan et al., 2014).

3.3.1 Third party logistics involvement in projects

Many academic works have concluded that the manufacturing industry is highly disjointed and conflict trotted because of the large number of smaller firms (Hawken et al., 2013). Many parties with different knowledge and skills such as designers, engineers, suppliers etc. coordinate and control projects. Since they are so diverse, they may not have the same goals and objectives in a project, which can create conflicts and prompt argumentative behaviors. Under such conflicts, the concept of 3PL can then come into play. The discussion about the 3PL being argumentative and competitive has been leading the focus towards promoting non-argumentative relationships which creates the impression that collaborative methods are solution for the logistics sector (Clements & Wilson, 2009). The last couple of years have been seeing an increased interest in collaborative concepts such as 3PL, which has become an important reality for the movement and storage of raw materials and information in the present day supply chains (Leuschner et al., 2014). Salokivi et al. (2013) express an important issue about 3PL; they found that it was evident that cost savings and concentration on core activities was the key for collaboration but that the lack of flexibility undermined attempts to reasonably capture the benefits of collaboration. In spite of everything, it is still in argument if a collaborative way of working can create success, but it has been evident that new 3PL organization needs to be encouraged in order to increase business success (Lieb and Lieb, 2010). It also needs to be decided to what extent the 3PL can be inaugurated in order to reach a collaborative achievement within a manufacturing project.

Trust and commitment are mentioned repeatedly to be crucial in 3PL and trust between stakeholders can take a long time to be established. Stefansson (2006 p.81) pointed out that the degree of collaboration (trust and commitment) within a project team increases over a frame of time. That being said, Stefansson (2006 p.82) considers collaborative roles as a good option in production business when it comes to achieving the goals, purposes and sustainable advantages in material flow. Sharing values and sharing knowledge is thought to be the main drivers of industrial results through 3PL engagement (Fu et al., 2011). Sharing knowledge (new ideas or innovation) within the collaborative attitude is a way of achieving lead-time reduction targets of a project. If the 3PL provider is able to timely hand over a project or service, cost savings is realized and the client is more likely to engage constantly in the 3PL job, which forms the basis for a symbiotic relationship. Stefansson (2006) goes further emphasizing that third party logistic (3PL) is seen by many in the public sector as a way of moving away from the argumentative relationships in manufacturing projects and approach a more collaborative method of handling projects. Another key issue why 3PL is encouraged and engaged in industrial services is ‘Quality’ (Ghosh, 2016; Osorio et al. 2016; So et al. 2006) which is discussed in the later part of this research.
3.3.2 Success Factors in 3PL

Different standards and methods have been considered as ways of identifying success factors in 3PL. The consideration methods have multi-criteria problems because of the complex process involved, especially where multiple tangible and intangible criteria need to be deliberated upon (Aguezzoul, 2014). Some 3PL success factors found in recent research are long-term relationships, building a history of favorable experiences, information systems to manage inventory and the use of information systems (Mothilal et al., 2012). One of the factors that intensify better 3PL project participation is the contractors and the suppliers’ early involvements (Van et al., 2008). New ideas (including shortcut approaches) increases with the early involvement and the risks of these partners disassociating due to difficulties during projects are reduced considerably. An example of success factors is identified in the case study of a 3PL firm rated fourth-position in the Korean logistics industry. The firm’s system disclosed how the company encourages supportive assets such as novel technological innovations, managerial improvement, and promotion in the organizational learning culture to achieve worthy advantages compared to leading competitors (Kim et al., 2008).

Several characteristics must be present before a logistics outsourcing arrangement between a contractor and a client can be considered as 3PL (Wagner and Sutter 2012): Such characteristics may include:

- The provision of a wide range of services
- A customer-specific solution
- Establishment of a contract
- A long-term duration of the relationship
- Joint efforts to advance the cooperation, and
- Fair sharing of benefits and risks

Into the process, contributions or inputs into innovation project may settle around:

- Capital
- Knowledge and
- Testing opportunities

3PL Implementation

Implementation of 3PL in a project involves many principles and may include supplier, manufacturer, and customer (Osorio et al. 2016). It encompasses also many concepts including, materials management and physical distribution management of products or services as shown in figure 5. Supplier, manufacturer, and customer are sometimes the three key-players in industrial manufacturing (Aguezzoul, 2014). 3PL can be engaged on either one or both the materials management or the physical distribution management units. Both the inbound and outbound logistics are coordinated properly as stakeholders seek to make best use of the reliability and efficiency of distribution networks (Senthil et. al. 2014). Moreover, the paths to 3PL implementation in inbound and outbound (NCC’s current practice) including outsourcing (author’s recommendation) logistics is what this thesis is all about. A clear set of goals empowers a company to focus on the right path (Sparvero et. al. 2016). 3PL implementation steps include information about firm’s supply chain management. The goals educate and offer value on the selection of a good logistics provider, which sometimes requires opinions for excellent supply-chain management, and conducting open researches to enable proper identification and selection through a list of earliest 3PL competitors. It is important to review the suitability of 3PL firms in order to determine for example the equipment locations and or the 3PL’s technical strength, distribution strengths and or weaknesses as well as their service areas regarding delivery locations. In other words, the focus for example in this research is to be on the delivery site with regard to the 3PL location,
which will help in excluding 3PL firms that cannot effectively address the practical requirements.

![3PL Connections Diagram](image)

**Figure 5: 3PL Connections**

An inbound 3PL logistic implementation (material management) issue under asphalt production can be the measurement of the aggregates, which has huge performance effect on the asphalt-mix (Chandan et al., 2002). Chandan et al. (2002) maintains further that designing thorough-functional asphalt pavements entails developing methods to measure rapidly and precisely the different aggregate shape properties and most decisively, relate these properties to performance. The characteristic physical structure of aggregates has been acknowledged in several researches to be the shape property that has the major influence on the performance of the asphalt mix. Bessa et al. (2014) also share the same view and maintained that the shape properties of aggregates such as sharp corners, form, and texture of surface greatly influence asphalt performance.

Given the above circumstance, factors that may influence 3PL implementation on asphalt production can be those integrating the strategical and operational targets, which can be evaluated with a four level framework; i) planning activities, ii) performance targets, iii) performance attributes of logistics operations and iv) logistics operations (Kayakutlu and Buyukozkan, 2011). Depending on the client’s choice to embrace any or all of the frameworks, s/he may choose to use more or less of the earlier mentioned success factors. It is necessary to use systematic assessment on 3PL prior to implementation. The systematic assessment can be based upon the risks involved, even though the noteworthy feature in todays’ rapidly evolving business nature, encouraged by the innovation, interaction, technologies, globalization etc. is the increasing occurrence of risk in virtually every aspect of our lives (Samvedi et al., 2013). Osorio et al. (2016) have developed a multi-criteria approach under a case study for implementation of 3PL with huge considerations focused on risk. The project was carried out on a company with customers in 15 North American countries, whose suppliers are from both locals and internationals.

In trying to tackle the problems associated with implementing 3PL supplier for this thesis, three potential suppliers can be picked following Osorio et al. (2016) recommendations under the following criteria:
- Structural Alignment: It covers aspects related to cultural and technological compatibility of the companies involved.
- Management Aligning: Includes aspects of the affinity between the management styles of the companies involved, including the quality management system and corporate social responsibility programs and risk management (particularly operational risks).
- Financial skills: Evaluate the aspects of financial position and bargaining power of suppliers.
- Operational skills: Includes the activities and skills of logistics operation.

3.3.3 Logistics challenges of Industrial Products/Components

**Product Life Cycle (PLC)**

In industrial engineering, the life cycle of a product has been reviewed from different perspectives by many authors (e.g. Cabeza, et al. 2014; Polat & Bektaş, 2015) including, assessment, energy analysis, cost analysis standpoints etc. The reviews revealed PLCs’ effects not only on a company’s research and development (RD) but also on environments and logistics activities. The concept of product’s life cycle has been in existence for many years, and it is an influential code for manufacturers in order to make a profit and stay in business. In Baker (2008) study, a revelation is made regarding a business unit that perceived short product life cycles in their warehouse but quickly decided thereafter to engage logistics contractors whose speeds are guaranteed in delivering fast the products to their various destinations. In other words, a major part of a products life circle lies in delivery-speed.

Example of a lifecycle of a product is shown in Figure 6.

![Figure 6: lifecycle of a product](image-url)
As illustrated, the life cycle of product traces a product’s development from extraction of raw materials, design & production, packaging & distribution, use & maintenance and ends with reuse & recycling that is when the products vanish into the earth or returned back to design & production as indicated using the right-handed-blue arrow at the center of figure 6. Sometimes the return process of the product back to design & production goes through the research and development (RD) or innovation processes (Fu et al., 2011) which implies that there are possibilities for continues improvement or revitalizing the product once again (Lean Production). During the first-three phases of product life cycle, the supply for the product may grow at an increasing rate and sometimes the demand may peak again after reuse & recycling phase. For asphalt industries where “more than 95% of asphalt production materials (by weight) consist of aggregates” (Akbulut and Gürer, 2007 p.1921) the delivery time between design & production and use & maintenance decreases very fast because hot mix asphalt according to Harvey & Popescu (2000) and Hanson, (2001) gets cold quickly if exposed to air. Hot mix asphalt should be paved on the road (or used for another purpose) as quickly as possible. There are tendencies for hot mix asphalt to form lumps, stall pavement, and easily flagged when failed to be used or launched in a project within an estimated short period. That intensifies the pressure to launch and deliver products at increasing speeds. The challenges for logistics under such scenario is not just understanding this life cycle, but also practically managing the delivery of the product.

On one hand, Polat & Bektas (2015) research is of the view that life cycle assessment can be used to measure the environmental effects of materials, products, processes, or systems during their whole lifetime from creation to disposal. The objective of Polat & Bektas (2015) project was to test and compare the environmental impacts of different hot mix asphalt products by means of life cycle assessment. The practical unit selected for analysis under the study was one-ton asphalt production. A comparative life cycle assessment was also carried out using life cycle assessment software SimaPro® with Impact2002 plus a database. Procedures from ISO 14040:2006 were also used during the course of the analyses. The results from the software underscored the estimated environmental performance of asphalt production in terms of a number of selections such as carbon footprint, resource and energy intakes and many environmental impacts. Based on the comparisons and between three specified types of asphalt products, it was established that an average of 10 percent reduction of environmental effects could be achieved when the less bitumen is used in the asphalt production. Simultaneously, carbon emission was 5 percent higher in the asphalt binder-type production where bitumen needs to be kept warm. Therefore, it can be said that life cycle assessment can provide a useful evaluation between products and ready to lend a hand in making decisions, which in turn becomes a game-changing strategy for Logistics in treating supply chain as a continuous uncut process that lowers supply chain expenses.

On the other hand, Cabeza et al. (2014) in their reviews, summarized and organized their handiwork using various literatures dealing on life cycle assessment, life cycle energy analysis, and lifecycle cost analysis. The study is carried out for environmental evaluation within the construction industry with huge emphasis placed on engineering constructions. Initially, Life-cycle assessment was defined by Cabeza et al. (2014 p.395) as “a tool for systematically analyzing environmental performance of products or processes over their entire life cycle, including raw material extraction, manufacturing, use, and end-of-life disposal and recycling”. The study’s analysis showed that most life cycle assessment and life cycle energy analysis are carried out in what was referred to as “exemplary buildings” (Cabeza et al., 2014), which are structures that have been planned and erected as low energy buildings. However, there were very limited studies on conventional buildings, which are buildings such as those commonly found in inner cities. Cabeza et al. (2014) acknowledged that comparing structural constructions are difficult to evaluate because of so many strong arguments,
including a) large in scale, b) complex in materials and their functions, c) time-based in dynamic due to limited service life of building components, and d) changing user requirements. Besides, Cabeza et al. (2014) recognized that in structural projects, construction productions are largely less problematic than most manufactured goods structure because of the unique character of each structure. Thus, there is a restrained quantitative data in the study about the environmental effects of the production and manufacturing of construction materials, or the real process of building and demolition, turning environmental assessments of the building industry into a huge challenge.

3.4 Reliability of delivery equipment

**Bathtub curve**

The reliability aspect of industrial engineering study describes the failure rate of an equipment utilization using a graphical design (bathtub curve) shown in figure 7. No designer can still be associated with the origin of Bathtub curve. Nonetheless, the bathtub curve occupies significantly an important place in reliability engineering, especially in the equipment use in transporting aggregates in this study, justifying the failure rate strategies for improving the reliability of vehicles (delivery equipment) use in delivering materials or services to various points within the Industry. However, the curve consists of three periods of operation cycles namely, infant mortality period with a shrinking failure rate followed by a normal life period also known as “useful life” with a short and relatively constant failure rate. It concludes with a wear-out period, which displays an increasing failure rate. In reliability engineering, focus and concentration is only on the useful life part of the bathtub curve, since logistic management is only interested in “maximizing the equipment usage” (Benda et al., 2005). The bathtub curve does not describe the failure rate of particular equipment in its place; rather the curve defines the comparative failure rate of entire units of products over
time. More or less under infant mortality period, single units will fail rather early, hopefully others could last until wear-out, and some could relatively fail during the long period (normal life). The first period is described by a decreasing failure rate, consisting of failures caused for instance by defects and mistakes. The second cycle keeps a low and somewhat constant failure rate; consisting of random failures characteristically caused by ‘pressure beyond power’. The third phase displays a constant growing failure rate, consisting of failures due to wear-out owing to fatigue or depletion of materials, for example “lubrication in depletion in bearings” (Poornima, 2003 p.423).

In bathtub curve model, it is also imperative to introduce the theory of ‘Mean Time Between Failures’, which is a “manufacturers term” (Milković et al., 2009) used in products’ detailing and promotion, often denoted by ‘MTBF’ which is applied when the causal distribution in a component has a constant failure rate, for instance in an exponential distribution. MTBF is different from ‘mean time to failure’ denoted by ‘MTTF’, which measures average time to failures within a hypothesis that the failed component cannot be repaired. Mean Time Before Failure or MTTF illustrates the average time to failure of a component, despite for example failure rate increase over time (wear out condition). Hence, some units would fail before the mean life of the machine, and some would survive even longer. For example, a device or component unit specified as having an MTTF of 10,000 hours suggests that some of the units would essentially operate longer than 10,000 hours without failure. A unit with a higher MTBF in years can still display wear out in shorter years and estimating higher warranty of a component can be difficult (Akbarov & Wu, 2012; Speaks, 2010 p.4). However, using MTBF to describe the failure rate of exponential distributed unit applies that the MTBF is equal to the inverted failure rate. For example, a component with an MTBF of 2.5 million hours per day (24 hours):

$$\text{MTBF} = \frac{1}{\lambda} = \frac{1}{\text{failure rate}}$$

Failure rate = \(\frac{1}{\text{MTBF}}\) = \(\frac{1}{2,500,000 \text{ hours}}\)

Failure rate = 0.0000004 failures / hour.
Failure rate = 0.0004 failures /1000 hours.
Failure rate = 0.04% / 1000 hours. N/B: There are 8,760 hours in a year.
Failure rate = 0.0035 / year.
Failure rate = 0.35% / year.

Note that 2.5 million hours is 285 years.

Mean time between failure (MTBF) is often denoted with Theta: \(\theta = 0.35\% / \text{year}\). Thus, by no means are any of these components expected to operate for 285 years in reality. In other words, long before 285 years of use, a wear-out condition will start prevailing and the population of the components would leave the normal life period of the bathtub and ignite upwards the wear-out curve. However, during the useful life period, the ‘constant’ failure rate will be 0.35% per year, which also can be expressed as an MTBF of 2.5 million hours. Torell and Avelar (2004) have argued that ‘Mean Time Between Failure’ is among the basic measures of a system’s reliability emphasizing that ‘the higher the MTBF number is, the higher the reliability of the product’ (Torell & Avelar, 2004 p.5).
Logistics activities, movement, and delivery of products constantly make use of mechanized system of operation and every mechanized component is tied to a group having a risk of failure (Elsayed, 2012 p.59). To launch reliably these operational cycles and guarantee reliability, the mechanized system needs to be tied with timely and appropriate logistics solutions in order to maintain the equipment. Reliability under the circumstance is defined as ‘the probability that a machine or equipment will operate or a service will be provided properly for a specific operating time-period and conditions without failure’ (Elsayed, 2012 p.3). However, equipment maintenance is among issues in Logistics challenges since failures of the part of equipment can occur randomly during operations (Dohi and Yun, 2006) therefore identified faults on the equipment ought to be repaired immediately otherwise equipment should not be put in use, depending on the hazardous nature of the fault anyway. To ensure that delivery equipment do not fail to the extent that it would not perform its duty, put employees or visitors at risk; it is often recommended to conduct a routine check on the equipment in an efficient manner (Wilson, 2007). It also important to practically tests the reliability of the equipment by applying mathematical formulas. The tests in this study is carried out using statistical formula ‘probability distributions’ (Elsayed, 2012 p.64) stated in the next section.

Nevertheless, ‘equipment selection’ (Ekipman et al., 2003 p.1) have been identified as one of the most important factor affecting production and construction design, especially excavation sequences, production planning etc. While using Analytical Hierarchy Process (AHP) method during selection of the equipment in an open pit mining, Ekipman et al. (2003) were able to point out these factors as being both qualitative and quantitative according to structure of the selection. Despite many pros of the approaches used in the study only few applications of AHP model to quarrying production industry were reported in the research, for example ‘the partial ranking of primary stripping equipment in surface mine planning and fuzzy algorithm’ (Bandopadhyay, 1987) which Ekipman et al. (2003) claimed deals with the process of ranking alternatives after determining their rating. Thus, the study was directed towards a research for an optimal loading-hauling system in an open-pit mine. The purpose of the study however, implicates selection of equipment based on best loading-hauling order from a mine to a power station to be launched in an open-pit coalmine located in Orhaneli, Turkey.

The circumstance surrounding the study is that the extent of open pit in the project was 1200 meters long by 400 meters wide with an overall 75 meters of heap to be removed in three 15 meters high benches. There was an average thickness of 7 meters of coal being mined at one bench alone. The final 25 meters of heap from surface was mined using dragline. The face slope on each bench was 75 degrees while overall pit inclination was 45 degrees. The average weather temperatures varied between plus 30°C and minus 6°C. The average yearly temperature during and prior to the research was 14°C. Notwithstanding, among the sampled equipment used in the case study included, Caterpillar, Champion, Komatsu, and Volvo, the only selected front-end loader equipment with bucket capacity of 5.5-6 m³ was Volvo. The selection of Volvo as the only front-end loader therefore could have been due to its reliability functions. Nevertheless, Hughes and Ferrett (2015 p.124) have offered how the frequency and nature of equipment maintenance should be determined through risk assessment taking full account of:

- The manufacture’s recommendations
- The intensity of and frequency of use
- Operating environment (e.g. the effect of temperature, corrosion, weathering)
- User knowledge and experience and
- Risk to health and safety from any foreseeable failure or malfunction.
On the other hand, instead of focusing on the above system for equipment maintenance, it is also important to apply some engineering knowledge in order to block or reduce the likelihood or frequency of failures of the equipment, which is also a determined way of handling the failures that do occur on equipment. Reliability under the circumstance is defined as the probability that a component, device, system, or process will perform its intended function without failure for a given time when operated correctly in a specified environment (Waghmode and Patil, 2016). Therefore, ‘Poisson distribution’ (Elsayed, 2012 p.481) is the applied probability distribution in dealing with the reliability (failure rate) of the equipment in this case. Failure rate is the number of failures per unit time during the operation. However, the author applies Poisson distribution because:

a) The failure rate of the studied equipment is random
b) The hazard rate on part of the equipment is constant and
c) Only applies to the useful life period of an equipment

The Poisson distribution in this case is therefore a discrete probability distribution for the counts of failures that occur randomly on the equipment in a given interval of time (or space). The formula is denoted as follows:

If \( x \) = the number of failures in a given interval,

**Expression for Poisson distribution:**

\[
P(x) = \frac{\lambda^x e^{-\lambda}}{x!} \quad x = 0, 1, 2, 3, 4, \ldots
\]

\( P(x) \): probability of failure occurring \( x \) times in time \( t \)

\( \lambda \): constant hazard rate (also known as failure rate)

\( e \): is the base of natural logarithms (2.7183)

! means to multiply a series of descending natural number (\( x \)).

The above formula and many more are tested in the discussion part of the study while relating empirical findings with theories. Exponential distribution (Elsayed, 2012 p.279) is also used in calculating how much the delivery equipment will work without breaking down, which is often denoted with the following formula:

\[
f(t) = \lambda e^{-\lambda t}
\]

or

\[
f(t) = \frac{1}{\mu} e^{-t/\mu}
\]

Both formulas mean the same, however, one of the advantages of the second formula is simply that it can be clearly visible that the mean of the distribution \( \mu \) (mu) describes the mean value. The probability density function representing the probability that the machine will survive over \( t \) time units or the probability that the component will not fail within \( t \) time units is represented by:

\[
R(t) = e^{-\lambda t}
\]
Where,
\( \lambda \): failure rate
\( t > 0 \)
\( e \): is the number 2.71838 (natural logarithms)

Another theory applied in the study is the ‘queuing theory’ (Frenkel, et al. 2013) used in understanding the waiting time of product or materials before and after arrival. Queuing theory involves construction of a model so that queue measurements and waiting time of material arrival can be predicted. Joshi et al. (2013 p.140) study revealed that many studies have been carried out involving queuing theory application especially in reliability engineering. Example of Queueing theory model is shown in figure 8.

![M/M/1 Queuing System for Crusher](image)

**Figure 8: queuing system for stone aggregate**

Where;
\[ \lambda = \text{Arrival rate} \]
\[ \mu = \text{Service rate} \]

The Queuing theory enables statistical analysis of several related processes and in this research the lumps of stones arriving at the (back of the crusher) queue, waiting in the queue (a storage process), and being served at the front of the queue (stone crushing) before departing as aggregates (different sizes) to the batching plant. The model above can be analyzed as follows:

- Stones are crushed in order of arrival.
- Mean = \( 1/\lambda \) (exponential inter-arrival)
- Mean = \( 1/\mu \) (exponential service times)

Queuing theory has created many positive changes in organizations (Frankel et al. 2013). Tucker & Singer (2015) in their study maintained that one justification for queuing theory is that it guides towards successful problem solving because observing a problem in context improves managers’ knowledge of the difficulty, its adverse impact, and its roots. It is believed that queuing theory also increases managers’ inspirations and dispositions to work with frontline workers and other team leaders to resolve problems. In other words, with queuing theory, valued problems (e.g. fault identification) that consume resources are dictated (Tucker & Singer, 2015) and Frankel, et al. (2013) suggest strong commitments toward queuing theory as it is necessary to prevent the queue of unsolved problems while advocating that manager’s commitment to the theory has shown success in implementation and completion of projects.
4. Empirical Findings

The empirical findings from the interviews and the case company’s documents are presented in this section. The results as part of the critical issues are divided into three major parts: Material haulage, Reliability, and third party logistics. Other critical issues that rose from third party logistics include, trust, commitment, and communication.

4.1 Material Haulage

The department of asphalts production at NCC Gävle manages and coordinates the transportation of material from blasting site (quarry) to the asphalt (batching) plant. The economic development in NCC asphalt production department is based essentially on the use of stones for asphalt production. When asked about factors within the production department influencing material haulage, the quality control manager (QCM) among many other things said ‘I think we get any of our problems solved as quickly as possible’. Because aggregates accounts for 92 to 96 percent of hot mix asphalt (HMA), so ‘we do the transportations by ourselves for quality reasons’ said the QCM. Only Volvo equipment were seen working in NCC’s premises including those on redundancy. One interviewee states that Volvo equipment is so reliable that everyone has trust in it as in “it will cost the company more lost per hour of production if the delivery equipment breaks down.” One of the operating managers said ‘I think Quality and Safety are parts of Volvo construction equipment’s DNA. The cost of hauling these materials in terms of petroleum product and maintenance of the equipment did not have any significant effect on the supply management during the year 2015 despite budget overshoot from 70,000 kronor per month to 320,000 kronor due to increase in HMA demand.

While aggregates are being moved in different dumps (see figure 4.) within the premises, the operators, and drivers are responsible for the security of the material and must comply with weight and safety standards. To provide operational expertise long before different stages of the haulage processes, operators and drivers of the equipment are provided with lectures, in order to assist with definition of the user requirements and detail project specifications. During the decline in operation for continuous blasting, the NCC haulage system (managers) also backs up the feed bin area, always maintaining the connection of the material flow between the feed bin and the belt conveyor section. Higher emphasis is placed on time reduction in terms of waiting time, for example, utilization of two Volvo dump trucks so that one can be loaded while the other one is in transit. Special unit from the municipality (Gävle commune) responsibly for regulations and environmental rules periodically comes to check the earth (land) quality in terms of oil leakage and spills from NCC’s haulage activities. In summary quality was mentioned virtually by all the interviewees on different occasions.

4.1.1 Quality

NCC has a sophisticated system of quality checks and control or its transportation activities, thus conducts quality laboratory tests for both aggregates and HMA (See appendix 2 & 3). The standard temperature for asphalt production for example is 160°C, but NCC produces at 120°C without undermining the quality of asphalt being produced – we care about the environment, said the QCM. The total number of registered laboratory test samples in the year 2015 is 1273. The quality control system is time constraining and we sometimes employ some people temporarily to perform the tasks (scientific calculations), said the QCM. NCC has a planned and execution system that monitors the haulage process performance and
product quality, which ensures that the state-of-control is maintained properly according to Head of the department (HOD). Several arguments rose among the interviews on what ‘quality’ constitutes. The HOD goes further saying that NCC has a quality risk management that establishes a control strategy. Data management and statistical tools are available tactical controls that NCC uses for measuring and analyzing parameters, and to identify qualities. In the course of examinations and cross-examinations of materials and hot mix asphalt (HMA), sources that identify variations affecting delivery performances and product quality for future continual improvement activities are tackled vigorously. Trafikverket that has the responsibility for continuing planning of the traffic system for roads, aviation, rail transport and shipping specifies the type of asphalt to be produced, which indirectly helps in quality control of materials to be used. NCC has in place a feedback system that puts both quantitative and qualitative activities in check. The systems for example use signals to inform hazards (on equipment), fire outbreak, and computer malfunctions.

4.2 Reliability

When asked how reliable the means and the most constantly used vehicles that transport these materials are, several meanings to equipment reliability were identified within the case company. Reliability at NCC is ranked mostly important among all qualities of transportation in the company. On one hand, the Transport manager (TM) expresses equipment’s reliability to mean how reliable their coordination is in delivering aggregates from blasting site to the crushing plant down to the batching plant. ‘The blasting, the dumping, the crushing, and the batching stages are all well-coordinated together - I think we are a reliable company since none of our customers have ever been disappointed’ said the TM. One of the operation managers (OPM) explained, to appreciate the quality of the aggregates that NCC produces it is better to experience it than to assume it, NCC is a reliable company, asphalt production can only be related to or classified by its technical approach to qualities, and that increases the reliability of NCC’s vehicles and reputation. ‘That also explains how reliable the delivery equipment is’ said the OPM. The only item that fails all the time is the computer panel on the machines dashboard which is of no risks at all’ the OPM said. The OPM goes further saying ‘reliability to us means all movements - timely or untimely movement of aggregates to various designated points within our company –NCC’.

Nevertheless, the author recorded that while aggregates move on the crusher’s conveyor belt (machine) an average of three stones falls off the conveyor belt every two hours during operation. On the other hand, and in terms of mean time between failure ‘MTBF’ on the Dump Truck, there was no information on that, rather NCC has also Volvo dump trucks model-C140 with reliability of 0.90 for 7000 operation hours at 14 tons of operating weight, among NCC’s series of equipment. The total number of delivery vehicles (equipment) within NCC’s premises is seven in numbers.

4.3 Third party logistics

NCC welcomed the growing vigor in relations between 3PL and the manufacturing industries. All NCC’s interviewees recognized how the prospective strengths and effects of 3PL together underpin the great potential in 3PL involvement within the company. They noted that 3PL development and rise in the global manufacturing industries has created new opportunities to further deepen and extend 3PL engagement, that 3PL would foster economic growth and future inclusive development within the company as well as to meet economic challenges. The company agreed to scale up their thinking towards 3PL involvement in the
project and vowed to show strong commitments towards a closer 3PL dialogue at the asphalt department level.

On the other hand, when asked why NCC does not use a third party logistic to manage material haulage, one of the interviewees said that outsourcing our company is farfetched because outsourcing means rendering their job positions useless. The management of NCC has never heard about 3PL concept. However, they know that many companies use other companies in transporting goods and services. Nevertheless, the Transport manager (TM) believes that their material delivery system is reliable and has very smooth flows given the fact that the transportation distance within NCC’s complex is quite a short distance and requires no third party involvement. NCC is of the view that every step of the transportation cycle of materials from blasting site to production plant is managed properly. However, ‘any measure that would bring along large benefits to the asphalt department is highly welcomed’ said the QCM. The QCM continued ‘remember it is not within my power to take or make decisions about this type of change’. Notwithstanding, the following critical issues rose when asked about engaging a third party logistic to manage NCC’s material haulage:

**Trust**

3PL is usually an external logistics and not internal, the interviewees have doubts regarding to trust a 3PL company to manage the affairs of NCC material transportation business, since it requires economics of scale with multiple customers. The factors responsible for this issue are that the 3PL company may use operators that know neither English nor any Scandinavian language. Most NCC’s documents are written in Swedish. That will not make it any easier to communicate freely with the 3PL operators and will makes it even harder to trust 3PL performance in terms of whether they are doing what they are supposed to do, expressed the head of department (HOD). Again, it is somehow difficult, four of the interviewees argued, to transfer activities that NCC previously performed internally to third party logistics providers meaning redefining NCC’s organizational boundaries. Other factors that affected the trust issue were that the TM asked if the 3PL operators would understand the terrain/environmental issues for example the weather (winter seasons), the seasonal types of transmission and cooling fluid systems of the machines. TM went further asking if the 3PL have ever planned work with respect to environment, considering for example, the level of noise pollution. Nevertheless, the HOD argues that it seems only when the economy and services of a firm fluctuate out of control that firms may go for 3PL providers. For now, ‘I still believe that we can comfortably take care of our resources – we have so much trust on each other’ said the HOD. Notwithstanding, the QCM insists ‘how am I going to trust the 3PL with the hazardous chemical products use in running tests, again, am I going to teach the so called 3PL how to perform records in our database about materials and other information in order for our products to be approved by the Trafikverket for our clients’.

**Commitment**

One of the interviewees during the interviews was indicating that the 3PL might be less committed to the relationships between NCC, Trafikverket, and their clients than NCC itself. He goes further saying that the 3PL might not be willing to tackle and solve problems that occurred immediately since they are not really the original drivers of improvements for the customers’ relationships, quality management, environmental issues, and community affairs. In NCC’s material transportation business, delivery trucks are never overloaded – for safety reasons and that implies NCC’s utmost good faith. How are we sure that the 3PL will abide by such principle, asked the QCM. He continued, though there are assurances that a 3PL will do the right thing, it all boils down to costs and the level of required financial commitment in engaging them. In other words, would the 3PL’s overall cost of the entire supply chain
In nutshell, the interviewees had feelings that the 3PL would be more of a less provider of accurate delivery services, more of a bureaucratic institution, than NCC who has been in this line of business for decades. While the 3PL providers, according to three of the interviewees may be hard workers in terms of manual laborers and may not have knowledge of the state of art equipment, which we all have, it might be difficult to start teaching them all over again, on how our machines function. Alternatively, are they coming with their own machines, asked the OPM, understanding our cultural differences and work ethics assuming they are foreigners could be another big issue, the NCC managers believed.

**Communication**

One of the interviewees asked ‘since most giant companies like ours (NCC) engage other international bodies in the name of 3PL to manage their transportation affairs, what language could they be speaking? For example, ‘I speak only Swedish and English and some of our workers can only speak Swedish’ said the HOD. This could be a major key issue or conflict in reality if we engage a 3PL, no matter how cheap their services may appear, said the one of the OPMs. The working language of NCC is Swedish and English but Swedish takes more priority for all intense and purposes. The researcher observed that all workers were communicating in Swedish during the three-time visits. Then the researcher asked this follow up question; what if the 3PL company is a Swedish company where everyone could be speaking Swedish? One of the interviewees responded ‘why can’t they mind they own business. Another said it is then ok; it could work well then because, we understand ourselves easily, we respect each other’s opinions. He continued ‘in America and Britain for example senior staffs are being referred to as ‘yes sir and yes ma, but we do not here in Sweden - I suppose you should know that’ and the researcher responded ‘Yes I do’. The HOD further said – ‘I envisage conflicts arising because of 3PL involvement due to language barriers; though we are independent department here in Gävle, but we are being controlled from NCC’s headquarters, which are in constant communication with us on daily bases. The 3PL may have their own rules, regulations, work ethics, etc. that may force NCC’s transportation system to function faultlessly, but how would they convey and relate those issues to NCC’s management Offices, argued, the QCM. Two of the managers speak in addition a Scandinavian language.

5. Analysis & Discussion

In this section, the empirical findings are linked with theoretical framework and were analyzed. Some engineering tools (statistical formulas) are used also in this section.

5.1 Material Haulage

NCC’s unwillingness to engage 3PL in their material haulage is not in line with Leuschner et al. (2014) observations on the increase in many firms’ quests to collaborate with 3PL provider, which has become a reality for the movement of raw materials in present-day supply chain management. However, such unwillingness to engage in 3PL also did fit in many authors (e.g. Eisenhardt & Graebner, 2007; Lieb & Lieb, 2010) definitions of supply chain management with focus on ‘cost reduction’. This is observed in the TM’s (Transport managers) question on whether the 3PL’s costs would be lower than that of NCC’s current cost of material delivery. Such a ‘cost’ linked question increases the probability that 3PL may
be embraced at NCC as some point as cost plays very significant role in determining if a company will engage a 3PL or not (Salokivi et al. 2013) which is also in line with Smith (2012) reasons for why companies engage in outsourcing. Also specified under literature review through the definition of logistics, is the dynamic solution offers by logistics in handling the uncertainty associated with product delivery, which NCC seems to have control over it. NCC offers flexibility not only to the traits offer by 3PL but also handles their aggregated delivery in a cost effective manners as advocated by Investopedia (2016) resulting in NCC’s budget overshoot from 70,000 kronor per month to 320,000 kronor, as seen in the empirical findings. That proves another reason why 3PL is not being welcomed in the project for now.

In addition, and as described by the life cycle of a product in the literature, a products varying-characteristics change over its life and determines how quickly the product must be delivered to its designated points. Thus, a three dimensional (3D) argument can be developed under the context, on one hand and naturally, aggregates (stones) have long lifespan, therefore 3PL can be engaged in the aggregates haulage within the project since the product has no expiry date and any delay in its delivery will not affect the products life cycle (PLC). On the other hand, aggregates constitute more than 95% of asphalt production materials (Akbulut and Gürer, 2007) which also is acknowledged by the quality control manager (QCM) in the empirical findings. It becomes very important to manage properly the aggregates supply chain process since ‘once aggregates are mixed with bitumen and formed asphalt its delivery period shortens’ (Harvey & Popescu, 2000; Hanson, 2001) therefore engaging 3PL in the project under the context can be very risky (Chou et al., 2009; Samvedi et al., 2013) perhaps due to controlled asphalts delivery time. Then again, NCC wants to manage their SCM in-house without 3PL involvement since they know when to launch or deliver products and their supporting logistics infrastructures reflect the changes over the life cycle of asphalt, and they may not want to gamble disappointing their customers, which has never happened before as seen in the empirical findings.

Nevertheless, other SCM characterization with focus on the environment (e.g. Eisenhardt & Graebner, 2007; Lieb & Lieb, 2010) was seen to be in line with Transport manager’s thoughts, following his question on whether the 3PL have ever planned work with consideration to environmental noise pollution. In line with the case study, it is evidently revealed how unwilling NCC is in embracing the concept of 3PL’s performance in managing their material haulage probably because of outsourcing negative performance impacts cited by Smith (2012) in a case carried out in USA. This argument also holds water in line with the literature, as Bengtsson et al. (2009) in the face of strong arguments for outsourcing-research observed that previous studies on outsourcing results have confirmed few or conflicting outcomes concerning the impacts of outsourcing on performance.

Although the arguments presented so far support both in favor and against 3PL model implementation at NCC’s material haulage just as Marasco (2008) identified some struggles within ideal 3PL definitions, yet there are a number of potential drawbacks, the author observed that need to be recognized as having implication while trying to inaugurate 3PL at NCC asphalt production department Gävle. Firstly, the integration of 3PL within an internal material haulage of an asphalt project is uncommon, that could produce negative impact on performance assuming a 3PL concept is implemented at once in the project, which could affect logically both NCC’s costs and regional built reputation. Such potential negative impact goes against Bengtsson et al. (2009) notes on many firms’ increased cooperative interests in outsourcing, likewise Leuschner et al. (2014) notes on many firms’ ‘increased interest’ in collaborative concepts like 3PL involvement in movement and storage of raw materials in present days’ supply chain management. Given the circumstance, 3PL system in this context cannot be entrusted with managing the complex nature of NCC’s material
haulage despite Binh (2016) and Potti & Saurav (2016) claims that 3PL is designed to manage huge, complex, and customized projects with lengthy durations.

5.2 Reliability

All interviewees acknowledge reliability as a ‘key issue’ whereby the TM expresses equipment’s reliability to mean ‘how reliable NCC is in delivering aggregates from blasting site to the crushing plant down to the batching plant’. As pointed out in the empirical finding, only Volvo equipment were seen working at NCC’s premises (quarrying business) including those on redundancy. However, in Ekipman et al. (2003) study on ‘equipment selection’ in quarrying production industry, Volvo equipment was also selected as the only front-end loader equipment with a 5.5-6 m³ bucket capacity among all the sampled equipment including Caterpillar, Champion, and Komatsu. It is possible to postulate based on both the empirical finding and the literature that the trustworthiness in Volvo equipment in delivering its function based on bucket capacity in quarrying production is reliable. Logically, the production and transportation capacity of a quarrying business lies on the loading equipment and if the loading equipment is not reliable enough to handle the products tonnage, there will be a loss in production due to for example frequent breakdowns. Therefore, it is possible that with or without 3PL involvement in this research project, a good and high reliability can still be achieved while using Volvo equipment since its reliability can be said is based on the equipment manufacturers quality. Thus, pushing further the innovative concept of 3PL involvement in the project under the context could demonstrate ‘a low shown-interest’ as seen in the empirical data or could result in recording another conflicting result concerning the impacts of outsourcing on performance (Bengtsson et al. 2009 p.35).

While Hughes and Ferrett (2015 p.124) offers how the frequency and nature of equipment maintenance should be determined through risk assessment, one of the interviewees merely said that NCC’s technical approach is a quality determinant factor, and that their approach increases the reliability of NCC’s vehicles and reputation. Contrary to both Hughes & Ferrett (2015) and one of the interviewees, ‘Poisson distribution’ as advocated by Elsayed (2012) is used in calculating the reliability of the delivery equipment in this case since failure rate of equipment occur randomly (Dohi and Yun, 2006) likewise in calculating the probabilities of the stone-falls from the crusher’s conveyor belt. As observed from the empirical finding, an average of three stones falls off the Crusher’s conveyor belt every two hours during operation period and when such observation is merged with ‘Poisson distribution’ (Elsayed, 2012 p.481), the following equations can be derived.

Assuming the manager works for 8 hours and takes one-hour off for break. The probability distribution for $X$ and the number of stones that will fall off the conveyor belt during the 7 hours of operation would be: The mean number of stone-fall is 3 stone-falls in 2 hours, or 1.5 stone-falls per hour. This means that over seven hours, the mean number of stone-falls will be:

$$\lambda = 1.5\text{ stone-fall /hour} \times 7\text{ hours} = 10.5\text{ stone-fall.}$$

The equation therefore would be:

$$p(x) = \frac{\lambda^x e^{-\lambda}}{x!}$$

$$= \frac{(10.5)^x e^{-10.5}}{x!}$$

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To estimate for example, the probability that no stone (0 stone) falls in seven hours of operation would be:

\[ p(0) = \frac{(10.5)^0 e^{-10.5}}{0!} \]

approx.: 0.000027 = 0 percent

Furthermore, to calculate for example the probability of 10 stones falling off the conveyor belt during operation would be:

\[ p(x) = \frac{(10.5)^{10} e^{-10.5}}{10!} \]

approx.: 0.1236 = 12 percent.

Therefore, the result of the above equation implies that for every 7 hours of operation, some quantity of aggregates is being misplaced since the probability that no stone (0 stone) falls in seven hours of operation equals 0%. It is possible that one and or more of the following reasons could have triggered the stone falls: a) the fault could be from the crushing machine’s conveyor belt, b) the topography of the area where the crusher is positioned, c) the fault could be a defect i.e. the manufacturer’s fault etc. Given the circumstance, the author concurs with Van et al. (2008) theory in the sense that early involvement of 3PL in the project could have helped in pointing out the fault. Furthermore, the Poisson distribution formula has helped under the situation in determining the percentage of stone falls during operation at the quarry, which mathematically affects the total quantity of aggregates produced by NCC in the given input. Who knows how long this has been going on? On the other hand, it is possible that with or without a 3PL involvement in the project the application of ‘queuing theory’ (Frenkel, et al. 2013) could have probably helped in identifying the stone falls (fault). It is also possible that NCC is aware of the stone falls since the researcher did not discuss the fault with them. NCC may have purposefully neglected the stone falls since the quantity of stone falls is so infinitesimal to affect the overall quantity of aggregates being produced. The above circumstance boils down to same purpose of this study, in other words, under what scenario in this context is it appropriate to outsource to a 3PL (Min, 2013, p.144).

Nevertheless, Elsayed (2012 p.279) has backed using ‘exponential distribution formula’ in finding failure rates of equipment, and when that is applied to the case study of NCC having a Volvo dump trucks Model-C with a reliability of 0.90 for 7000 operation hours at 14 tons of operating weight, the following result is derived:

Assuming that failure time is exponentially distributed, the failure rate is estimated as:

\[ R(t) = e^{-\lambda t} \]

\[ 0.9 = e^{-\lambda 7000} \]

Remember that “ln( )” means the base - e log, so “ln(e^{-17000})” = “log_e(e^{-17000})”

\[ \therefore e^{-\lambda} = \frac{ln0.9}{7000} = \frac{-0.1053605157}{7000} \]

\[ = -1.505150224*10^{-5} \]

\[ = 0.00001505 \]
approx.: 0.00002 (failure rate).

So, the result of the above equation implies that a high reliability is placed on Volvo construction equipment since the failure rate is very low (0.00002) assuming the equipment is operating at 7000 hours carrying 14 tons’ maximum weight on its bucket. Exponential distribution formula has helped in figuring out the failure rate of Volvo equipment, which followed Elsayed (2012) postulation. It also implies that at maximum capacity the Volvo equipment’s bucket is equally reliable owing to the low failure rate. Nevertheless, NCC’s selection and use of only Volvo equipment may have been based on its low failure rate and the bucket configuration. That was observed also in the literature following Ekipman et al. (2003) study on selection and use of only such a brand-named equipment with a bucket capacity of 5.5–6 m³ among varied list of construction equipment in the quarry production project. Again, 3PL involvement within the context could have made no significant change in the failure rate of the equipment since the reliability of the equipment (0.90 for 7000 operation hours) is already fixed. Perhaps due to poor maintenance (Hughes and Ferrett, 2015) feared by the managers (empirically observed), the 3PL could make mistakes if entrusted with management of the equipment since they are not the ‘original pioneers of the project’ as pointed out by one of the interviewees.

Given the situation above, is it possible to apply and estimate the theory of ‘Mean Time Between Failures’ a “manufacturers term” (Milković et al., 2009) use in products promotions since the failure rate is already known to be 0.00001505? Neither days nor years were specified in the problem. The only information about the problem is that Volvo dump trucks Model-C has a reliability of 0.90 for 7000 operation hours at 14 tons of operational weight. Therefore, the possible calculation for the MTBF that can be derived following the sequence of theory is as follows:

\[
\text{Failure rate} = 0.00001505 \text{ failures/ hour} \\
\text{Failure rate} = 0.01505 \text{ failures / 1000 hours.} \\
\text{Failure rate} = 0.1505\% / 1000 \text{ hours. N/B: There are 8,760 hours in a year.} \\
\text{Failure rate} = 0.131838 / \text{year.} \\
\theta = 13\% / \text{year.}
\]

Therefore, the MTBF of the Model-C dump truck cannot be calculated or determined. Based on \( \theta = 13\% / \text{year} \), the useful part of the equipment is gone. The failure rate of the machine is already at wear out stage due to high failure rate. Notwithstanding, the overall MTBF of the component is not stated. Neither days nor years were specified to support the calculation. However, there are 8,760 hours in a year and the total specified operation hours is 7000, where is the 1760 remaining hours in a year? Therefore, the evaluation is wrong. Notwithstanding, the knowledge about equipment’s reliability functions has helped so far in determining and estimating the failure rate of the delivery equipment used in hauling aggregates in the project and that is among the reasons ‘reliability’ is underlined as among the critical issues in the project.

From the empirical findings it is evident from the OPM’s statement that ‘The only item that fails all the time is the computer panel on the machine’s dash board which is of no risks at all’ follows Hughes and Ferrett (2015 p.124) recommendations (point number iv & v) in terms of equipment maintenance and reliability. However, the constant failure rate as seen in the case requires the use of exponential distribution in analyzing the reliability function. Nevertheless, since the computer system of the delivery equipment has a constant failure, supposing the computer manufacturer determines that the machine has a constant failure rate
of $\lambda = 0.1$ failures per year in normal use. The maximum warranty for example if not more than, 3% of the computers are to be returned to the manufacturer for repair would be:

$$e^{-\lambda t} = R(t)$$

$$e^{-0.1*t} = 97\%$$

Remember that “$\ln(\cdot)$” means the base $e$ log

$$= ln(e^{-0.1*t}) = ln0.97$$

$$-0.1*t = ln0.97$$

$$-0.1*t = -0.03046$$

$$\therefore -0.1*t = -0.03046$$

$$\lambda = 0.03046 \text{ years (maximum warranty)}.$$  

On the other hand, predictions in software (for example computer panel) reliability are made based on the software reliability model and the ultimate goal of software reliability modelling is the reliability prediction. Assuming the reliability of the computer for one year is placed higher than 0.999 for example $0.99999^{365}$. Therefore, the developer declared that the reliability of the computer for one year is equal to $0.99999^{365}$ because faults detected in the system are commonly assumed can be removed, making the software reliability a growth process. However, that was not the case above, which would have given both the equipment and the operators a good quality measure.

Nevertheless, warranty these days has simply become a marketing tool used in assuring customers of superiority in the reliability of the product and the manufacturer’s pledge towards a post product sale services. Thus, estimating higher warranty is difficult in some engineering components (Speaks, 2010 p.4) for example under the circumstance the computer, which also corresponds with Akbarov and Wu (2012) postulation that even a unit with a higher MTBF can still display wear out in shorter years than earlier estimated. Therefore, engaging 3PL in the project as this thesis explores, could have made no changes in the failure rate of the computer in terms of the warranty period since the 3PL are not the computer manufacturer.

5.3 Third Party Logistics

According to Van et al. (2008) one of the factors that intensify better 3PL participation in a project is the contractors (NCC) and the suppliers (3PL) early involvements in projects, which the author tried to motivate within the case company.

Quality

In the introduction part of this study, Chandan, et al. (2002) argued that quality performance is the key to a good HMA. Could that be the reason why NCC always and must collaborate with Trafikverket as seen in this case? May be or maybe not. Hot mix asphalt (HMA) production follows a procedure and are produced mostly at $160^\circ C$ (Chandan, et al. 2002) and NCC follows suit as seen in the case, but deviates by dropping the temperature down to $120^\circ C$ because of environmental concerns. Such concerns were also observed in the
literature as the objective of Polat & Bekaş (2015) project focused on the environmental performance of asphalt production in terms of a number of selections such as carbon footprint, resource and energy intakes etc. Yet the quality of HMA produced at NCC is same quality as that acclaimed by Chandan et al. (2002) when it is tested at the NCC’s laboratory according to the QCM. On the other hand, both Chandan, et al. (2002) and QCM arguments could all be erroneous because what determine good and quality asphalt are the shape properties of the aggregates as emphasized by Bessa, et al. (2014). One could argue that quality remains among NCC priorities, which is among various reasons why companies do not outsource their logistics functions especially for the fear of losing control of the operations according to Salokivi, et al. (2013 p.393). The interviewees voiced out that the collaborative atmosphere and the will of solving problems collectively with 3PL may not result in better qualities for their products. That is inconsistent with Stefansson (2006) belief that satisfaction regarding quality is higher through shared collaboration with 3PL in projects.

Empirically, quality is found being described as a positive stimulus for asphalt production in terms of cost efficiency and on-time delivery. In addition, those are among the reasons ‘quality’ is underlined as among the critical issues in this thesis. Though such a clear set of goals empowers NCC to focus on the right path according to Sparvero, et al. (2016), however, 3PL is still viewed preferably when dealing with projects of huge complexity according to information from both interviewees and some authors (Belso-Martinez, 2010; Mothilal et al., 2012). Therefore, the author considers that 3PL can be involved in NCC’s internal logistics for ‘cost reduction purpose’ (Liu and Wang, 2009) since collaboration among them ‘is generally believed to increase efficiency and decrease costs’ (Stefansson, 2006 p.81). Lowering of cost could help in increasing further NCC’s profits after all ‘sharing responsibilities and increasing profits is among main responsibilities of firms’ (Friedman, 1970) that was also supported in the literature. Evidently, the department had a positive budget overshoot from 70,000 kronor per month to 320,000 kronor (NCC, 2015) in financial commitment (only on petroleum consumption). In addition, a firm with a general sales of SEK 62 billion in 2015 with approximately only 18,000 employees (NCC, 2015) can incorporate a third party logistics into their system at least for the purpose of more job creation within the municipality. Nevertheless, according to Stefansson (2006) many in the public sector see 3PL also as a way of moving away from the argumentative relationships in manufacturing projects, which the author witnessed during the argument among the interviewees over what quality constitutes.

Trust

Trust became underlined as among the critical issues when engaging third party logistics in an asphalt-manufacturing project. While the interviewees fear that the cultural difference between them and the 3PL might affect the company’s reputations, trust became an apparent issue as “we have so much trust on each other” expressed by the head of department (HOD). The level of ‘unbuilt trust’ between NCC and the potential 3PL has started hanging on a balance even though the integration is not yet in place. Most of the interviewees expressed low level of trust assuming the department should embrace right away a third party logistic firm. Impressively, only one out the five interviewees cared-less about trust instead had his focus on commitment as seen in the findings. As Stefansson (2006) agued and stipulates that trust within a project team increases over a period. That went against NCC’s reasoning and understanding of trust in 3PL-involved project, instead to them, 3PL involvement in the project will bring about ‘kicking them out of jobs’ and such a fear led to series of questions as seen in the empirical findings. Nevertheless, for the interviewees to endorse their tendencies towards developing trust in outsourcing, the department should rather focus on disclosed systems that encourage organizational intercultural learning, for example ‘open innovation
management technique’ (Bengtsson, et al. 2015). That is believed would help in ‘trust development’ likewise in creating huge advantages for NCC compared to other competitors (e.g. in asphalt production) as suggested by Kim, et al. (2008). Therefore, a majority cause of the interviewee’s inability to embrace a 3PL system is conceived as many struggles accompanied by a number of hindrances in terms of language, communication, and commitment.

Commitment
Whereas trust and commitment are mentioned repeatedly under some of the literatures used in this thesis, commitment became outstandingly an issue in the empirical findings and was equally underscored as among the critical issues when engaging third party logistics in an asphalt-manufacturing project. The interviewees had feelings that the 3PL firm would not show strong commitment to aggregates transportation management, rather could be a less provider of accurate delivery services and more of a bureaucratic institution than NCC itself. It can be argued that such feelings went against Stefansson (2006) postulation which pointed out that ‘trust and commitment’ within a project team increases over a frame of time, even though under the circumstance the theory was not empirically tested, which could have counteracted the author’s argument. However, such feelings can be superseded if NCC together with the potential 3PL co-workers can keep themselves motivated by showing their commitments to the overall challenges and demands facing aggregates transport at the department. Examples of the motivations can be in form of encouragements of new skills development, improvement in operations processes etc.

Improvement in operations processes can follow Tucker and Singer (2015) and Frankel, et al. (2013) suppositions that suggest strong commitment towards queuing theory as it is necessary to prevent the queue of unsolved problems since manager’s commitment to the theory has shown successful implementation and completion of so many projects. Therefore, the author backs more commitment towards the queuing theory. It is believed that commitment towards queuing theory would help in determining production output, which in turn helps the profit structures of NCC including costs of inputs, pricing factors, and efficiency in the production process. In conclusion, a commitment towards such a reliability-engineering model (queue system) would rather help NCC to grow in union with a 3PL than ascribing commitment towards human behavior (attitude of the potential 3PL firm).

Communication
As a final point, virtually all the interviewees see communication as a factor that could hinder 3PL engagement into their system. There is no doubt that there could be communication problems assuming the 3PL firm is not Swedish speaking. Such a problem could rise from misinterpretations of responsibilities, which may result in hostility and blames among employees. It is believed that identifying conditions triggered by communication problems in an industry usually contains also helping organizations solve problems devoid of blaming others. Therefore, the author underlined ‘communication’ also as among the critical issues when engaging third party logistics in an asphalt-manufacturing project. Following Yinan, et al. (2014) acknowledgement on how many companies are beginning to apply the communication technique in external collaboration (3PL) to manage their product variety and customization, NCC should follow suit. It is important just like NCC-managers emphasized to consider communication as among the key issues before getting involved in any 3PL arrangement. This is because problems associated with weak communication coordination or poor listening skills could lead to unavoidable conflict. Finally, if NCC-asphalt department embraces 3PL and afterwards with communication problems, the chances are that time, investments, and productivity can be grossly affected.
6. Conclusion

In trying to explore the potential of 3PL involvement in the internal logistics department of an asphalt production project, proven by the theoretical and empirical findings, material haulage, quality, reliability, trust, commitment and communication are identified as critical issues influencing both the internal logistic of the project and incorporating 3PL into the process. In terms of material haulage, the likelihood of 3PL managing the supply chain of aggregates in the projects is very low. Noticeably, this study reveals that after explanation and introduction of the 3PL concept to the project, NCC expressed willingness to engage 3PL in their material haulage system but later backed out due to mainly those critical issues including ‘cost’ which was not underlined as being critical in this research. A result in the findings shows that NCC assumes that implementation and utilization of 3PL would have no enhancement effects on their costs.

As regards both reliability and quality which were equally underscored as being among the critical issues in this research, three perspectives have been shown in the study under which reliability can be viewed: a) the reliability aspects of this research, b) the reliability on the part of logistic management of resources and c) the reliability engineering. Based on this research, it is seen that the degree at which a good reliability and maintainability of delivery equipment can be realized through 3PL in asphalt manufacturing project is very low perhaps due to the failure rates in engaging Volvo equipment in the project is very low. As seen in this study, knowledge of equipment’s reliability functions is useful in determining the warranty period of the equipment used in asphalt production project. Consequently, even earlier or up-to-date engagement of 3PL would not have had any significant impact on the warrante period of the equipment. Those additionally conflict outsourcing impacts of performance (Bengtsson, et al. 2009). Quality management at NCC can be recapped as a management scheme for ‘customers and environmental’ focused business. Thus, there were uncertainties that 3PL involvement in the project might neglect those prerequisites. As seen in this research, it is possible that 3PL engagement in the project could have helped in figuring out the fault of the stone fall from the ‘crusher’s conveyor belt’ by keeping an eye on the queuing system as closer as possible, which is crucial for efficiency in production output. That becomes another positive move on why 3PL can be engaged in the project. Moreover, due to the vast rising and falling of this thesis areas, the mean (μ) became the dominating measure in the numerical analysis.

Trust and commitment have been stated frequently both empirically and theoretically to be crucial in firms’ considerations in engaging in 3PL collaboration. They were equally underlined as being critical in this research. In addition, trust between parties in industrial organization e.g. that of NCC and the potential 3PL firm can take a lengthy time to be developed. Trust becomes indispensable to outsourcing logistics since it provides a sense of safety as seen in this study. It is plausible to conclude that when manufacturing group members develop trust in one another, they feel contented to open up, take worthy risks, and uncover vulnerabilities because of trust. On the other hand, while the manufacturing firm in this study is seen charging commitment on the part of the potential 3PL, the author redirected the commitments’ focuses toward an engineering model (queue system) which is believed would help the manufacturing firm to grow while cooperating with a 3PL firm.

Finally, communication becomes the last identified critical issue when engaging 3PL in an asphalt-manufacturing project. Communication has equally played a fundamental role in all facets of this study including aiding in this thriving researched-3PL involvement in an asphalt-manufacturing project through the researcher’s multilingual skills; therefore, it becomes necessary that the case-company take both communication skills and abilities of
their employees seriously. That will create history of favorable experiences, information systems to manage inventory and the use of information systems (Mothilal et al., 2012).

6.1 Theoretical and practical contribution

On one hand, the outcome of this thesis resulted in contributions with regards to the field of academia. It is empirically validated through literatures that the underlined critical issues: material haulage, quality, reliability, trust, commitment, and communication influence 3PL engagement in an asphalt-manufacturing project. Yet, it can be noted that the implications for engaging 3PL in manufacturing or production projects differ among those issues. Furthermore, an exploration is carried out based on the theoretical data that is revised through consideration of the empirical findings resulting to exploring academic area that adds more knowledge to the field of supply chain management. To the best of the author's knowledge, this is the first carried out exploration within the academic literatures that shows 3PL involvement in asphalt-manufacturing projects particularly within the in-house material transportation, precisely within the context of supply chain management of aggregates. A gap has therefore been filled in academic world within industrial engineering literatures, which tries to serve as a foundation for further exploration in the area of 3PL involvement in asphalt-manufacturing project.

On the other hand, the practical implication of this study from side to side of the studied area is in its provision of guidelines for managers within quarrying companies that would want to outsource their in-house logistics activities to a 3PL firm. A guideline is shown on how to identify and manage equipment reliability risks that could adversely affect production operations, which is done by following specific models that enhance supply chain management of aggregates beginning from blasting stage, through the crushing stage to the final stage: the batching plant. Precisely, it is explained how application of engineering formulas on the delivery equipment will significantly enhance the performance, whereby this study outlines the significance of the application of ‘exponential distribution formulas’ (Speaks, 2010; Elsayed, 2012; Akbarov & Wu, 2012) in finding the failure rates of equipment. This research is carried out exclusively within logistics and industrial production context, the societal practical implications of the study is in its encouragement for industrial production drivers to create more jobs within their municipalities through the engagement of 3PL concept despite how satisfactory their in-house operation may look.

6.2 Limitations and further research

The generalizability of the concluding results in the study is limited based on selection of only one case-company involving only five persons for data collection and analyses. Due to the implication of being a single case study with only two in-depth interview questions and three focused interviews, it is believed that a broader perspective could have been carried out had it been more interviews and interviewees within the department were conducted and contacted. That became impossible anyway due to the limited time for this research and the company’s scheduled periods for data collections. Not all theories in the literatures were related to the empirical finding due to the time constraints of the research. The author recommends an inclusive method within a study where a great number of quantitative data collection and analysis (technique) is uniquely performed since it was not possible in this research due to the study’s design. Such inclusion is believed would strengthen the results of the research as well as its external validity.

Furthermore, the studied topic is part of a far-reaching in-house logistic management strategy with 3PL involvement within an asphalt-manufacturing project, geared towards
improving material haulage systems. Consequently, further research ought to explore whether single cases with different methods will generate same results like the current study. Besides, this study adopted only reliability functions as performance gauges for production equipment with focus on the useful period of the equipment. Performing such a similar study with a focus on a different period (e.g. wearing-out periods of the equipment) would be valuable especially in promoting ‘Lean Production’ and innovation management (RD) in industrial engineering. Finally, as this study has identified issues considered critical when engaging third-party logistics (3PL) in an asphalt-manufacturing project, the significance of each of these issues ought to be reviewed as well. It is suggested to carry out further studies on same topic on different companies running same type of business like NCC, with the aim of confronting possibly same issues as being critical.
Appendix

Appendix 1: Research questions

- In-depth interviews
  Could you introduce yourself, your position, and years of working in this company?
  Could you describe the nature of your business?

- Focused interviews
  What are the main factors within the production department influencing material haulage from the blasting site to the asphalt plant?
  How reliable is the means and most constantly used vehicle that transports these materials?
  Why is your company not using a third party logistic to manage material haulage?

Appendix 2: Different sizes of aggregates, source: NCC 2016

Appendix 3: Laboratory room for tests, source: NCC 2016
References


Wilson, R. H. (2007). The favored vendor: a department manager gambled on weak controls and lost. *Internal Auditor, 64*(6), 74-76.


