Empirical quantitative case study in operations management

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Abstract

This paper establishes the methodological framework for my research. My research can be classified as empirical normative quantitative research and empirical quantitative case study in operations management discipline. This is also can be considered as exploratory research and explanatory research.

Single case research design was employed for my research, because the single case design provides more opportunities for in-depth observation, and the single case design is appropriate for the extreme case, the typical case and the longitudinal case which are the cases of this study.

Keywords: operations management, case study, theory

This paper delineates the research methodology for my research. It starts by identifying the purpose of this research. In section 2, the methodological categories in operational management research are reviewed. In section 3, the suitability of the case study to research question is discussed. In section 4, the relation of theory to the case study is examined. In section 5, the case study research design is outlined. In section 6, the criteria for evaluating the research design are discussed. In section 7, the research procedure of this study is described. Finally, this paper is summarised in section 8.

1. Purpose of research

The purposes of research can be categorised as exploratory, descriptive and explanatory (Saunders et al., 2007). An exploratory study can be described as finding out what is happening, and asking questions and assessing phenomena in a new light; a descriptive study can be described as portraying an accurate profile of persons, events or situations; and an explanatory study can be described as establishing causal relationships between variables.

Recalling the aim of this research, the aim is "to identify an appropriate forecasting system for the spare parts demand in the SKN". The aim is achieved by answering research questions, which require ascertaining the nature of demand and the nature of the forecasting system in the SKN in the new forecasting strategy, as well as establishing the relationships between demand features and forecasting performances. Therefore, this study appears to be in line with an exploratory study as well as an explanatory study.

2. Empirical research in operations management

Operations management is defined as "the effective planning, organising, and control of all

resources and activities necessary to provide the market with tangible goods and services. It applies to manufacturing, service industries and *not-for-profit organisations*" (Waller, 2003, p. 875). This study focuses on model-based quantitative research in operations management discipline applied to a *not-for profit organisation* (i.e. the SKN). Model-based quantitative research refers to the research where models of causal relationships between control variables and performance variables is developed, analysed or tested (Bertrand and Fransoo, 2002). In causal relationships, a change of value α in one variable will lead to a change of $f(\alpha)$ in another variable, so that a model can be utilised to predict the future state of the modelled processes (Bertrand and Fransoo, 2002). In this study, future state refers to the change of performance variables such as inventory level and total costs. The change of forecasting method for spare parts demands can lead to a change in the performance variables.

Bertrand and Fransoo (2002) classified quantitative operations management research as axiomatic research and empirical research: a) axiomatic quantitative research indicates the process of achieving resolutions by the defined model; b) empirical quantitative research indicates the process of achieving resolutions by empirical findings. Bertrand and Fransoo (2002) divided axiomatic and empirical quantitative research into two sub-categories, namely normative research and descriptive, by their objectives: normative research has the objective of establishing policies, strategies and actions; descriptive research has objective of analysing model or describing the causal relationships in reality.

In terms of the classification scheme from Bertrand and Fransoo (2002), this research might be in line with empirical normative quantitative research, because the resolutions were achieved by empirical findings; and the objective of this study is to establish a forecasting policy for the spare parts by collating competing forecasting strategies (i.e. DF, TD, CF). EN

was claimed difficult to be verified, because controlling all relevant variables is impossible which is required for evaluating performance changes in EN (Bertrand and Fransoo, 2002). Verification is an important issue for this study. A simulation experiment was employed to evaluate the performance of forecasting methods in the controlled environment similar to reality.

Wacker (1998) classified operations management research as analytical (formal) research and empirical research for the purpose of theory building (see Table 1). In empirical statistical research, theoretical relationships are verified statistically in large external samples from reality; however, an empirical case study looks into small samples to test and develop complex relationships between variables to suggest a new theory (Wacker, 1998).

In terms of the classification scheme from Wacker (1998), this research might be in line with an empirical quantitative case study, because this study investigates only one case (i.e. the SKN) to test and develop forecasting strategy for the spare parts demand.

Table 1 Research category in operations management (Wacker, 1998)

		Types of research included
Analytical	Conceptual	Futures research scenarios, introspective reflection, hermeneutics, conceptual modelling
	Mathematical	Reason/logical theorem providing normative analytical modelling, descriptive analytical modelling, proto-typing, physical modelling, laboratory experiments, mathematical simulation
	Statistical	Mathematical statistical modelling
Empirical	Experimental design	Empirical experimental design, descriptive analytical modelling
	Statistical sampling	Action research structured and unstructured research, surveying, historical analysis, expert panels
	Case studies	Field studies, case studies

3. Choice of case study strategy

A case study is defined as "an empirical inquiry that investigates a contemporary phenomenon within its real-life context" (Yin, 2003, p. 13). A case study is a research strategy which concentrates on perceiving the dynamics present within single settings (Eisenhardt, 1989).

A case study is particularly good for examining "why" as well as "how" and "what" questions (among question series: "who", "what", "where", "how" and "why"), which are enquiries about a contemporary set of events over which the investigator has little or no control (Yin, 2003, Saunders *et al*., 2007). Especially, the "how" question is suitable for a case study because this question deals with operational links needed to be traced over time, rather than mere frequencies or incidence (Yin, 2003). Thus, the case study strategy is most often employed in explanatory and exploratory research (Saunders *et al*., 2007).

Looking back at the research questions in this study, “how” and “what” questions can be noticed (Table 2). These questions are appropriate to the case study. In addition, the case study is suitable for exploratory research and explanatory research which are the cases of this study. The research questions in this study lead both to theory testing and to theory development (Voss et al., 2002).

Table 2 Research questions

a) What is the nature of the spare parts demand in the South Korean Navy (SKN)?
b) What forecasting method is appropriate for the spare parts demand in the SKN?
c) Under what conditions are TD or CF superior or inferior to DF?
d) How can the spare parts demand be classified in order to produce the most superior forecast?

4. Theory in case study

A theory is defined as “a statement of relationships between units observed or approximated in the empirical world” (Bacharach, 1989, p. 498). Every research is based on theory as knowledge base.

4.1. Theory as knowledge base

There are three possibilities in which: a) existing theory provides no framework for findings; b) existing theory conflicts with findings; and c) existing theory is in accordance with findings (Eisenhardt, 1989, McCutcheon and Meredith, 1993, Yin, 2003). When the existing theories are indigent and the available literature provides no conceptual framework or hypotheses of note, such a knowledge base may not be a good theoretical foundation, and any

new empirical study is likely to assume the characteristic of an “exploratory” study (Yin, 2003).

On the other hand, the existing theories can be either in accord with the findings or in disagreement with the findings; in both cases, theory is important (Eisenhardt, 1989). Eisenhardt (1989) noted two reasons why enfolding literature which conflicts with the emergent theory is important: first, if conflicting findings are ignored, then confidence in the finding is reduced; second, conflicting literature generates an opportunity for refining the theory.

Additionally, theories for a case study can be very well-developed, especially where the object is to test or compare theories against empirical evidence, or the necessary foundation is available in the well-developed theories from other disciplines (McCutcheon and Meredith, 1993). Such cases are also important, because these theories bind together underlying similarities in phenomena typically not related to each other (Eisenhardt, 1989). This process of linking results might be essential in theory-building case study research, because the findings often rely upon a very restricted number of cases (Eisenhardt, 1989).

Theory is important in this study, in that the findings of this study are related to literature. However, theories related to the hierarchical forecasting (HF) for non-normal demand such as spare parts demand are not well-developed. Two research gaps were identified. However, the necessary theoretical base is available from literature for HF strategy as well as DF strategy in similar contexts.

4.2. Theory induction from data

Theory can be formed by either induction or deduction (Saunders *et al*., 2007). Wacker (1998) pointed out that the pivotal distinction between a case study and an analytical method is that empirical case study methods employ induction (i.e. depend on data) and the analytical methods employ deduction. If a theory is based on data, then a large amount of data is required, and case studies are a prime source of this research (McCutcheon and Meredith, 1993). The data can be quantitative data or qualitative data; they can be collected from either single or multiple cases (Yin, 2003). This study adopts an empirical case study strategy which employs an inductive method.

4.3. Generalisation

Eisenhard (1989) argued that binding the emergent theory with existing literature strengthens the internal validity, generalisability (external validity), and theoretical level of theory building from case study research. Internal validity demonstrates a causal relationship, in which certain conditions lead to other conditions; and external validity tests whether a study's findings are generalisable beyond the immediate case study (Yin, 2003). Generalisability is a particular concern for a sing case study as this research (Saunders et al., 2007). In this case, analytic generalisation can be claimed for the case study research (Yin, 2003). There are two kinds of generalisation from case to theory: statistical generalisation and analytic generalisation (Yin, 2003).

In statistical generalisation, generalisability is established by an inference made about a population on the basis of empirical data collected about a sample (Yin, 2003). However, statistical generalisation should not be considered to be the method of generalising the results

of the case study (Yin, 2003).

In analytic generalisation, generalisability is established by the process as: an existing theory is employed as a framework with which to collate the empirical results of the case study; then, when more cases appear to support the same theory, replication can be claimed (McCutcheon and Meredith, 1993, Yin, 2003). Analytic generalisation can be used in either single case or multiple case study (Yin, 2003).

This study employs analytic generalisation in single case study design. A single case study (i.e. the SKN) is used for advocating or refining existing theories. Then, the theory established from the case study could extend to other situations such as other militaries and business logistics.

5. Research design

Research design is the logical sequence that links the empirical data to a study's initial research questions; that is, the design discourages the situation in which the evidence is disconnected from the initial research questions (Yin, 2003).

5.1 Four components of research design

Yin (2003, p. 21) identified five components of a case study research design: a) a study's questions; b) its proposition, if any; c) its unit(s) of analysis; the logic linking the data to the propositions; and the criteria for interpreting the findings. Components a), b) and c) refer to what data are to be collected, whereas components d) and e) refer to what is to be done after the data have been collected (Yin, 2003). In this research, the four components a), c), d) and e) are considered because this research dose not make research proposition.

The first component is research questions. Although a case study is an inductive approach, a preliminary view of the general constructs or categories, and their relationships, is required; then, initial research questions behind the proposed study should be followed (Voss et al., 2002). Even though the prior questions are tentative, it is crucial to establish a well-defined focus at the start, and to direct the collection of data (Voss et al., 2002). The research questions of this research direct this research to focus upon the research topic, review the related literature and collect the spare parts data in SKN.

The second component, unit of analysis is relevant to the fundamental problem of defining what the 'case' is (Yin, 2003). Precisely specifying research questions leads into the appropriate selection of the unit of analysis (Yin, 2003). As shown in Table 2, the research questions seem to lead into the one unit of analysis; that is, the spare parts supply system in the SKN. Once a general definition of the case has been established, other clarifications in the unit of analysis become important: for example, specific group of people, district boundary, or specific time boundary(Yin, 2003). Specific three kinds of warships are clarified in this study. Since these three kinds of warships began to be commissioned in the early 1980s, they have been utilised in major roles during Naval operations (Saunders, 2006). The time boundary is decided from January 2002 to November 2007, because the Naval maintenance data system, which is the major data source, has been stabilised since 2002.

The third component, linking data to propositions is a way of relating the data to the propositions (Yin, 2003). In lieu of the proposition, research questions are considered to be the objectives to link the data to. In order to relate the data to research questions a), the spare parts demand and the current inventory control methods of the SKN in the SKN will be

analysed; to research question b), forecasts will be generated with the data by the competing forecasting methods and compared with each other; to research question c), the superiority of the competing forecasting methods under different condition such as the accuracy measures, the equipment groups and the demand features will be examined; and to research question d), the superiority of the competing forecasting methods in the classification model will be examined.

The last component is the criteria for interpreting the findings. The experiment which adopts competing forecasting methods is interpreted using an appropriate accuracy measure (i.e. absolute measures and relative measures to another method). This will be verified by simulation (i.e. derivative measure).

5.2 Choice of the single case design

Table 3 Choice of number of cases (Voss et al., 2002)

Choice	Advantages	Disadvantages
Single cases	Greater depth	Limits on the generalisability of conclusions drawn. Biases such as misjudging the representativeness of a single event and exaggerating easily available data
Multiple cases	Augment external validity	Less depth per case

Voss et al. (2002) discussed case study research design in terms of the number of cases. They categorised it as single cases and multiple cases, and illustrated the advantages and disadvantages as Table 3. Single cases have an advantage of greater depth. In this study, the single case design (i.e. the case of the SKN) is expected to provide more opportunity for in-

depth observation.

However, this single case design might have limitations (Leonard-Barton, 1990, Voss et al., 2002). Firstly, single cases have limits on the generalisability of the conclusions, because models or theories are developed from one case study; secondly, the limit of generalisability implies the risks of misjudging the representativeness of a single event, and of exaggerating easily available data. These risks are also present in multiple cases, although these are mitigated in multiple cases (Voss et al., 2002). However, as stated above, analytic generalisation in lieu of statistical generalisation can be used for single cases as well as multiple cases.

Yin (2003) postulated five rationales for single case designs (see Table 4). The case of spare parts supply in the SKN might represent a typical military logistical case. This case can represent an extreme case as well, for its extremely non-normal demand features. Moreover, this case is a longitudinal case using data from 2002 to 2007. These rationales could serve as the main reasons for conducting this single case study.

Table 4 Five rationales for single case design (Yin, 2003)

a) when it represents the critical case in testing a well-formulated theory;
b) when the case represents an extreme case or a unique case;
c) a single case is the representative or typical case;
d) a single case study is the revelatory case; and
e) a single case study is the longitudinal case: studying the same single case at two or more different points in time.

Furthermore, Yin (2003) sub-categorised the categorisation as a two × two matrix: single-case vs. multiple-case × holistic vs. embedded. A single case can involve more than one unit of analysis: a case study design involving embedded units is called an embedded case study design; a case study design examining only the global nature of an organisation is called a holistic design (Yin, 2003). The case of spare parts supply in the SKN can be considered to be a holistic single case design if the case is considered at the Naval supply centre of the Naval Logistics Command (NLC); however, the case can be regarded as an embedded single case design as well if the case is examined at the depots of the Naval bases. There are three major Naval bases and five minor Naval bases in the SKN (Saunders et al., 2007). This study employed the holistic single case design, because the focus of this study is to evaluate forecasting performance rather than inventory system performance. Therefore, the complex multi-echelon inventory system consisted of the eight depots (the first echelon) and the Naval supply centre (the second echelon) in the SKN is not required to be described in detail. The multi-echelon inventory system refers to the inventory systems in which materials flowing through the system are stored at different points, before reaching the customer (i.e. warships) (Slack et al., 2004).

6. Evaluating research design

Quantitative empirical case study research should be designed to test the validity of quantitative theoretical models and quantitative theoretical problem solutions, with respect to real-life operational situations (Bertrand and Fransoo, 2002). Yin (2003) discussed four tests relevant to evaluating the quality of a research design: construct validity, internal validity, external validity, and reliability.

Construct validity tests correct operational measures for the concepts being studied, and

ensure consistency between theory and the defined construct (McCutcheon and Meredith, 1993, Yin, 2003). Bertrand and Fransoo (2002) argued that operational research studies generally lack construct validity, because data could be affected by subjective judgements. However, the major data for this study, historical consumption of spare parts, was acquired from the logistical database in the NLC. Therefore, construct validity appears not to be a problem. However, the non-normal demand pattern causes distrust in the data generating process.

Internal validity demonstrates a causal relationship, in which certain conditions lead to other conditions (Yin, 2003). Internal validity is employed for explanatory (or causal) studies only (Yin, 2003). This study is to investigate the causal relationships between forecasting methods and forecasting performances. The causal relationships will be established by the various accuracy measures; and validated by simulation. The internal validity of the classification model will be established by the diagnostics of the model.

External validity tests whether a study's findings are generalisable beyond the immediate case study (Yin, 2003). External validity is a major barrier in conducting case studies (Yin, 2003). As mentioned previously, a case study relies on analytic generalisation. In a single case study design, the case of the SKN can be used in generalising existing theory. In addition, the case of the SKN can also be used in extrapolating the theory to other situations (e.g. other militaries and business logistics) relying on logical analysis.

Reliability tests whether the operations of a study can be repeated with the same results (Yin, 2003). Reliability was maintained by revealing every reference and every data source explicitly, and presenting every equation and every process in models adopted in the study

transparently, so that any calculations are able to be audited. In order to maintain the reliability of the forecasting performance, the forecasts generated were examined by a variety of measures such as absolute, relative, and derivative measures.

7. Research procedure

The research procedure of this study is described as Figure 1. As a model-based single case study, this study started from establishing the research questions in Chapter 1. As aforementioned, research questions are crucial to establishing a well-defined focus at the start and to direct the data collection. This is followed by theory development.

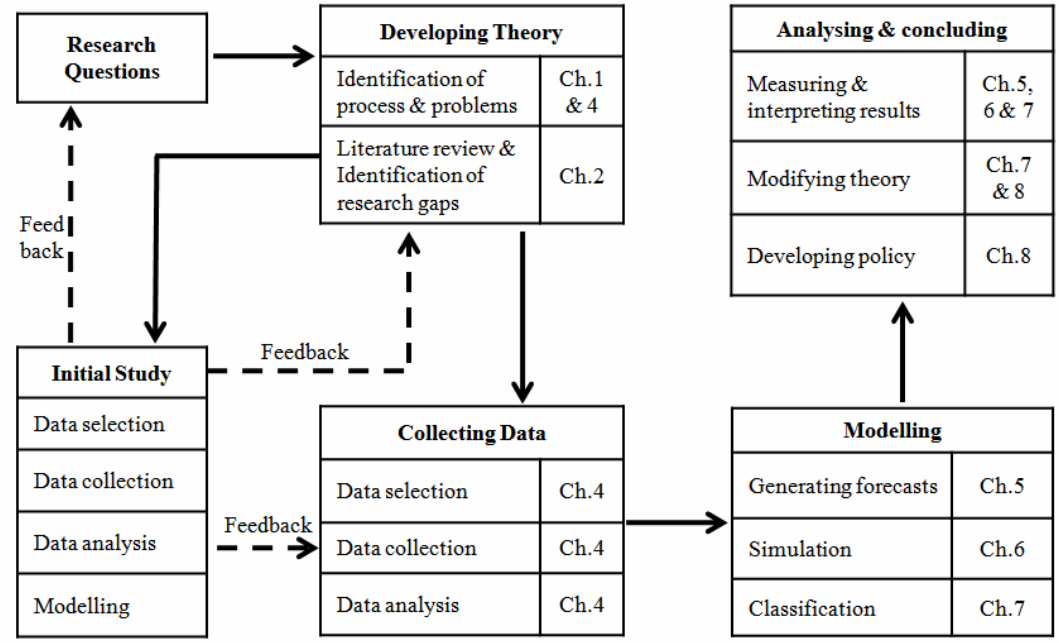

Figure 1Research procedure

In the theory development stage, the forecasting process of the SKN and its problems were identified in Chapters 1 and 4. After reviewing literature relevant to these problems, the research gaps are identified in Chapter 2. Then, initial study which combines initial data

selection, initial data collection, initial data analysis, and initial modelling is conducted. The initial study results provide feedback which requires further literature review. This feedback clarifies the research questions and guides further data collection. The stage of collecting data is described in Chapter 4.

Following the collecting data stage, the modelling stage is carried out based on the theory developed: the various competing forecasts are generated in Chapter 5; simulation is conducted to verify forecasting performances in Chapter 6; and the classification model is proposed in Chapter 7.

In the analysing and concluding stage, the results of empirical modelling is measured and interpreted in view of forecasting accuracy as well as the inventory context in Chapters 5, 6 and 7. Thus, internal validity can be established by the various accuracy measures. Depending on the results and the existing theory, the theory can be generalised as analytic generalisation. Also, the theory is expected to contribute to supply policy development of the SKN.

8. Summary

This paper presents a methodological framework for this study. The purpose of this study appears to be in line with an exploratory study as well as an explanatory study. As an operations management study, this study seems to be empirical normative quantitative research and empirical quantitative case study.

Since a case study is suitable for “how” and “what” questions as well as exploratory research and explanatory research, which are the cases of this study, this study chooses a case study as

the research strategy.

Theories relevant to this study are available from the existing theories, although the necessary theories are not well-developed for the context of this study. However, theories from similar contexts can be the theoretical foundation of this study. The theory of this study can be formed by an inductive method and can generalise as analytic generalisation.

Research design is the logical sequence that links the empirical data to research questions (Yin, 2003). The four components of research design are reviewed: research questions; the unit of analysis; the logic linking the data to the research questions; and the criteria for interpreting the findings. This study chose the single case research design, because the single case design provides more opportunities for in-depth observation, and the single case design is appropriate for the extreme case, the typical case and the longitudinal case which are the cases of this study. Then, four tests which can evaluate the research design are reviewed. Finally, the overall research procedure is described in this chapter.

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