Uncovering Barriers in Forecasting Uncertain Product Demand in the Supply Chain

Elias Abou Maroun[#1], Didar Zowghi[#2], Renu Agarwal[#3], Babak Abedin[#4]
[1] *Faculty of Engineering and IT, University of Technology Sydney, Australia*
[2] *UTS Business School, University of Technology Sydney, Australia*
[3] *Macquarie Business School, Macquarie University, Australia*

[1]Elias.AbouMaroun@alumni.uts.edu.au
[2]Didar.Zowghi@uts.edu.au
[3]Renu.Agarwal@uts.edu.au
[4]Babak·Abedin@mq.edu.au

***Abstract*—This paper aims to provide insights into the barriers of forecasting uncertain product demand in supply chain by focusing on the relative importance of the barriers for businesses, particularly the forecast practitioners and prospective forecast implementers. A exploratory, qualitative approach was adopted within an Australian electrical manufacture. Data was gathered through semi-structured interviews with 20 participants from different departments, including forecasting practitioners, supplier and customer of the Australian electronics manufacturer. Thematic analysis was conducted to confirm some of the existing barriers reported in the literature and identify emerging barriers from practice in industry. The study reveals that there are more barriers to choosing the right forecasting system or method and the main reason for poor forecast performance is intertwined between cultural, communication, product, market, environmental and technological themes. These themes lend empirical insights into the barriers still faced in many organisation today. The identification of end to end barriers in forecasting uncertain product demand of the electrical manufacturing industry have not previously been studied in great depth. This paper sheds insight, provides new knowledge and contributes to academic thinking.**

Keywords— *Forecasting, Uncertain Demand, Supply Chain Management, Electronics Industry*

1. Introduction

In today's global economy, the increase in competition, decreasing product lifecycles, product proliferation and product innovation have made forecasting uncertain product demand more complex. High demand uncertainty has been observed not only because of the nature of products but also because of institutional and regulatory pressures [1]. Uncertain product demand relates to customer orders that are not known in advance, where certain product demand is when standard orders are placed based on a known demand [2]. The critical issue for many organisations is the strain caused by the everchanging demand pattern [3]. Organisations are intensely under pressure due to competition and the expectation to provide customers with the product shortly after the customer orders that product. This next day or same day service expectation from customers creates a strain on the organisations' supply chain. The availability of information and the transparent marketplace has optimised consumer choices and hence forces organisations to revise their marketing strategies . Manufacturers must know what to produce now to supply the demand in the future and ensure they have adequate resources on hand to do this. Most supply chain management activities have sought to remove or reduce the uncertainty within a supply chain as far as possible [4]. Frameworks such as linking reactive and proactive strategies in order to achieve supply chain flexibility options [5] have been developed to deal with changing business environments. However, it is becoming impossible to remove or ignore sources of turbulence and volatility when forecasting; hence, supply chain managers must increasingly accept and adapt to uncertain environments [4].

The inaccuracy in product forecasting has dire consequences for the supply chain's intra- and inter-organisational levels [6]. Poor accuracy in the forecast leads to stockouts [6], excess inventory , and not achieving target service levels [7]. Accurate forecasting is complex and difficult due to the inter-related nature of the data series, the presence of unusual non-repetitive events, trend shifts in demand [8], and the antecedent factors of global sourcing [9]. Supply chains managers require robust methods and strategies that serve dual purposes. First, these strategies should help a firm reduce the cost and/or improve customer satisfaction under normal circumstances [10]. Second, the same strategies should enable organisations to better understand how unexpected disruptions occur, the impacts they will have on the flow of goods to meet customer demands

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[11] and how to sustain the organisations' operations during and after a major disruption [10].

Despite a relatively large number of studies in forecasting demand, there is a scarcity of research that shows the end to end supply chain barriers in forecasting uncertain product demand. More importantly, previous research only explored selected barriers or practitioners [12, 13] in forecasting demand. They did not consider the end to end supply chain barriers the investigated supply chains might face. We are motivated to provide an insider's account of the barriers faced in forecasting uncertain product demand. The results from extracting the barriers from the end to end supply chain within the Australian Electrical manufacturer motivates future work to reduce forecasting model errors. In this study the end to end supply chain includes a Supplier, Operations/Manufacturing department, Sales department, Finance and IT department, Category and marketing department and Wholesale customer.

Several studies [14-16] have found that in addition to the barriers with forecasting demand, the increasing use of judgmental adjustments in the forecast is a source of added demand management complexity. Eksoz, Mansouri [17] found judgmental adjustments cannot be ignored due to contextual information in uncertain demand. The study also identified the need for more focus and research on judgemental adjustments in forecasting.

To bridge this gap, our study performs an end to end interview study and gap analysis to find the differences between the barriers derived from the literature and the findings from the industry field study.

The following main research question guided our study:
What are the issues and barriers of forecasting uncertain product demand in the supply chain, their relative importance, for the business?

To answer the above question, we introduce a two-step exploratory research plan. Our first step was to undertake a thorough systematic literature review. Using the literature review findings in the second step, we conducted a qualitative analysis with 21 industrial interviews to gain a deeper understanding of the barriers found and develop the scope for future research. The objectives of the interviews were to: (i) identify the issues and barriers of forecasting uncertain product demand in practice, (ii) identify potential gaps in research and practice of forecasting uncertain product demand.
In this paper, we present the findings from the analysis of the interview data with practitioners from Australia Electrical Manufacture (AEM is a fictious name used in this study) who have experience forecasting from an electrical product manufacture, a supplier, and a customer of AEM. The case study company derives significant revenue from electrical manufactured products but also experienced poor forecasting accuracy, thereby making it a compelling case for research. The barriers identified are divided into two categories, namely, internal barriers and external barriers. Internal barriers are found to be within an organisations' internal environment made up of employees, management, communication and culture [18]. The external barriers relate to outside factors, for example, seasonality, government regulation and suppliers that can impact an organisation in its ability to forecast demand.

2. Theoretical Background

2.1 Uncertainty in Supply Chain Forecasting

Forecasting is the fundamental step of demand management that optimizes the customer satisfaction through the capabilities of the supply chain [19]. Forecasting product demand is a management process that most organisations wish to improve [20]. Understanding the future demand is a critical element in planning the manufacturing of products for future supply. Various forecasting methods have been developed over time based on two well-known approaches to forecasting: qualitative and quantitative. Qualitative methods such as executive opinions or forecasters own judgements, while quantitative techniques may be grouped under historical forecasts data, e.g., Single exponential smoothing, Naive method, Holt's and Winter's models. In the literature, statistical methods, like "time series" or "linear regression" [21], "Fuzzy and grey" [22], and "Lumpy demand"[23], are commonly used to estimate the future demand. Also, mixed or combined models [24] enable the integration of both approaches, e.g., Blattberg-Hoch. The most common approach to forecasting demand involves the use of a statistical software system that incorporates a quantitative forecasting method, such as exponential smoothing, to produce a forecast. These forecasts can then be reviewed and may be adjusted by forecasters to take into account additional circumstances expected over the forecast period, or to possibly correct any inadequacies in the system forecast [6].
There are three major types of uncertainty that plague supply chains in this context: uncertainty of the demand forecast, uncertainty in external process, and uncertainty in internal supply process [25]. These can be attributed to three forces: (1) supplier uncertainty, arising from on-time performance, lateness, and degree of inconsistency; (2) manufacturing uncertainty, arising from process performance, machine breakdown, supply chain performance, and; (3) customer/demand uncertainty, arising from forecasting errors, irregular orders [26]. In order to manage and reduce uncertainty in supply chain, frameworks such as [5, 27] have been

developed to deal with changing business environments by achieving better supply chain flexibility. However, achieving flexibility in organisations has been noted to be costly [28].

Traditionally supply chains had a 'make-to-stock' paradigm which in many cases have been replaced by 'make-to-order' where the final part of manufacturing or configuration of a product is postponed as much as possible, usually until a customer order is received [29]. This make-to-order model is particularly suited for organisations that produce customised products to satisfy demand in a market environment where there is a diverse customer taste and preferences, rapid developments in technology and globalization of management [30]. Organisations need to decide on the number of components they source or stock keeping units (SKU) they manufacture before the customer demands it in the next sales. This problem is known as *uncertain demand forecast* and has widely been studied in economics and supply chain management (SCM) [31].

2.2 Forecasting Barriers

The accuracy of demand forecasting is vital to manage customer relations successfully; it allows organisations to provide customers with the products or services they want, when and where they want them. Efficient product demand forecasting requires close cooperation of all departments within organisations, building strong collaboration with stakeholders [32, 33], and using all available data. This cannot be achieved without the support of integrated information systems [34]. However, many supply chains may not be shared due to barriers such as compatibility of information systems, information quality, trust, and confidentiality [35].

Demand forecasting improvement is a daunting task mostly restrained by forecasting barriers. The forecasting barriers create additional complexities from forecasting, such as complicated product supply networks, logistics bottlenecks, short product lifecycles, demand uncertainty, supplier reliability, and other factors . For example, in the fashion industry, Nenni et al. (2013) found that these barriers make forecasting demand particularly challenging. The additional complexities resulting from the forecasting demand barriers have also prompted the rise of sophisticated computer applications.

However, Ayers and Malmberg [36] state it is not necessarily true that complexity should be combatted with more complexity and that it is naive to think a single information system application or other approaches will be sufficient.

Moon [20] states three significant barriers in forecasting demand from the multiple companies that have participated in his research: 1. The culture is wrong. 2. The information system is the solution. 3. Management doesn't get it. He argues that when companies use outdated legacy systems that fail to provide adequate functionality, system improvement requires a straightforward implementation of a new, functionally richer forecasting system. Alternatively, the problem may be a lack of integration between the forecasting system and other upstream and downstream systems such as customer relationship management and enterprise resource planning; this problem can result in a manual transfer of data and possibly a lack of access among key users.

Some of the extant literature on the barriers in forecasting demand is summarised in

Table 1 Prior research on barriers in the supply chain

Discipline	Citation	Highlights
Food and Chemical Industry	[34]	The barriers in the integration of forecasting and functional planning
Fashion	[37, 38]	The barriers in forecasting are short selling seasons, demand uncertainty and a lack of historical data.
Electronics	[39]	There is a need to decrease organisational complexity to improve forecasting.
	[40]	Supply chain collaboration is shown to increase demand forecast accuracy.
Retail	[41]	The categorization of risks is key to identifying relevant mitigation strategies.
Pharmaceutical	[42, 43]	The importance of integrated procedures for in-market product demand forecasting and purchase order generation in the pharmaceutical supply chain due to budget constraints and limited space.

In summary, past studies have recognised the significance of barriers faced in forecasting uncertain demand and recognised the overall importance to the accuracy of the forecast. The existing studies on the barriers in the supply chain mainly focus on: (a) the high-level barriers in the supply chain [37], (b) supply chain risk categorization and mitigation [41] or (c) the barriers in implementing a demand planning process in an organisation [34]. The studies do not cover a holistic view of barriers in organisations forecasting the product demand process. A case study covering the end-to-end barriers in forecasting product demand in the supply chain is missing. This has motivated our investigation for a fine-grained field study on the end to end supply chain barriers that occur in a manufacturing organisation.

3. Methodology

Case study is one of the methods used in the design of qualitative study. A case study is expected to capture the complexity of a single case, and the methodology which enables this has. Additionally, case study is an approach that provides a practical inquiry which studies the current phenomenon within the real-life context.

3.1 Research Setting

One of the Australia's largest electrical manufacture and distributor (AEM) has a wide range of product portfolios focusing on serving the roadway & infrastructure, commercial & industrial, consumer and retail market segments of the electrical industry. AEM incorporates engineering and design, research, manufacturing, international sourcing, importation and distribution. It allows AEM to develop new products for consumer acceptance. It also offers flexibility in designing variations and bespoke designs from one unit to thousands of units. There are currently over 15000 stock keeping units (SKU's) ranging in complexity from small and inexpensive products to large heavy-duty products for industrial use. Most of these SKUs are variations of the main product types, either directly sourced from suppliers and are known to be box-in-box-out products or assembled in house from basic components and/or intermediate products that the company's suppliers provide.

In terms of the uniqueness of this context, most electrical manufacturers either purchase or manufacture their products overseas and sell their final finished goods to businesses (third-party providers), who sell them to other actors along with the SC such as retailers, distributors and end consumers. AEM's commercial business procures approximately 11000 components sourced from over 20 suppliers, manufacturing companies located mainly in China and some European countries. One of the suppliers is AEM's manufacturing plant, the sole manufacturing facility of electrical goods in Australia. The demand forecasting side of product demand is complex, as the customer base includes customers making a frequent or infrequent purchase of small or large quantities and expect immediate service. In contrast, large ''institutional" customers (hospitals, retail, sports stadiums, commercial buildings, industrial and large manufacturers) typically place large orders through contractors or wholesalers but usually allow a reasonably long delivery time. Thus the AEM industry provides a unique research context to study this important topic.

3.2 Data collection method

According to Schultze and Avital [44], interviews offer rich qualitative data when a topic needs deeper insight. Interviews acquire the views and thoughts of participants by speaking face-to-face with them and allowing participants freedom to express their thoughts and experience on the topic. Using the authors' supply chain knowledge and the knowledge gained from the systematic literature review, a set of interview questions were designed to identify the barriers faced by participants. The interviews were semi-structured and open-ended questions. Open-ended questions do not have any prescribed answer to be selected by participants. The questions were aimed at the three specific business units in the organisation. A set of generic questions was derived for all participants and a set of specific questions for the operations participants and the sales/category. This is so that the questions are targeted and relevant to each business unit function.

3.2.1 Field Study Design

The criterion for selecting the interviewees was that participants were involved in forecasting product demand or were impacted by it. Based on the criterion, the participants were from across the supply chain. The participants belonged to the following three business units: sales/category, operations and finance/IT. An external supplier and customer of AEM were also selected as they impacted the supply chain forecasting. Human ethics approval was obtained from the UTS Human Research Ethics Committee (HREC) before contacting any participants.

A total of 21 participants were invited to participate in the interview study; twenty participants accepted. The interviews lasted an average of 39 minutes. At the time of the interview, participants were given a consent form. They were asked to read it carefully and understand their rights. The participants were also briefed on their personal data, data safekeeping, and the complaints procedure to UTS HREC. The interviews were audio-recorded; however, participants were also informed that they were free to ask not to be recorded at any time during the interview. The names of the interviewees, the companies or their job titles will not be revealed in this paper within compliance with HREC's confidentiality obligation at UTS to accept this research.

4. Findings

In analysing our data, we were able to unravel specific details about the research topic, especially concerning the nature of forecasting uncertain product demand in a unique environment, uncovering the barriers in forecasting uncertain product demand. In answering our research question: What are the issues and barriers of forecasting uncertain product demand in the supply chain and their relative importance for the business. **Error! Reference source not found.**1 shows the top 10 barriers mentioned by the participants after the data analysis was completed. Some theme names come from the SRL e.g. seasonality and poor communication others purely from the thematic supply chain and their relative importance for the business.

Error! Reference source not found.1 shows the top 10 barriers mentioned by the participants after the data analysis was completed. Some theme names come from the SRL e.g. seasonality and poor communication others purely from the thematic analysis, e.g. lack of understanding and lack of data governance. Overall the barrier with highest number of mention is a lack of commitment.

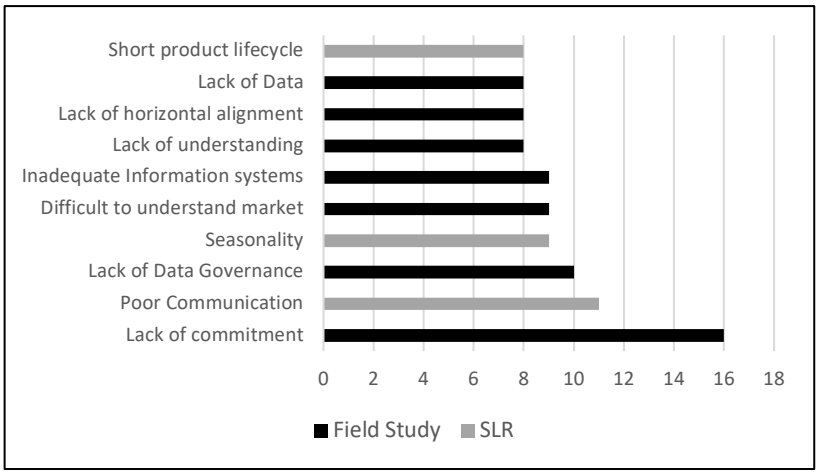

Figure 1 Top 10 barriers

The results in **Error! Reference source not found.**2 illustrate that each business group interviewed have a different set of their top 10 barriers. The sales and category teams are the only ones included in all the top 10 barriers.

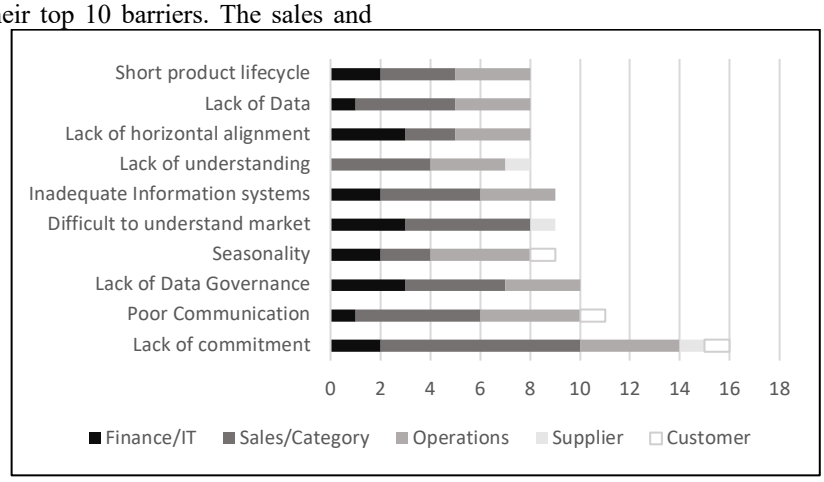

Figure 2 Top 10 barriers by interview groups

We found that the barriers could be divided into 6 main themes, these themes are:

1. Cultural Problems

This category relates to the behaviours and needs of supply chain stakeholders, including customer behaviour and their service/product needs.

This is evident in AEM, a sales and category group participant who indicated that AEM faces its own internal barriers in lacking commitment in the forecast, "*We all need to own this process not just the person that's having that conversation with the customer*

2. Communication Failure

This refers to the communication and collaboration between stakeholders of the supply chain

Another participant states that the business fails in communicating new generation products well, "*we haven't communicated a new generation of product through to our customers well and expect the product continually to have growth, instead it goes through a ramp process*".

3. Rapid Change in Product

This relates to barriers related to the organisations' products. A participant from the operations group has stated that the short product lifecycle is due to "*the speed that technology is changing*".

4. Market Competitiveness

Marketing covers a wide domain (e.g., branding, competitive behaviour, segmentation, advertising and positioning), It's been stated by participants that AEM is a sales-oriented organisation and not marketing, Flint [45] research shows that

organisations that have a market orientation are focused on gathering, disseminating, and responding to market data better than those that are not which enhances the effectiveness of their marketing strategies

5. Environment
The environment refers to either AEMS surroundings, including natural, seasonal and political forces that impact the environmental surroundings. The customer participant stated "*the holiday period impacts our projects and at most times we don't consider our suppliers holiday shut down and their own suppliers' shutdown as well".*

6. Inadequate Information Technology
This refers to the information technology tools/applications that are used in the organisation. The results for the technology category show that 16 respondents believe that inadequate information technology is a barrier for forecasting uncertain product demand

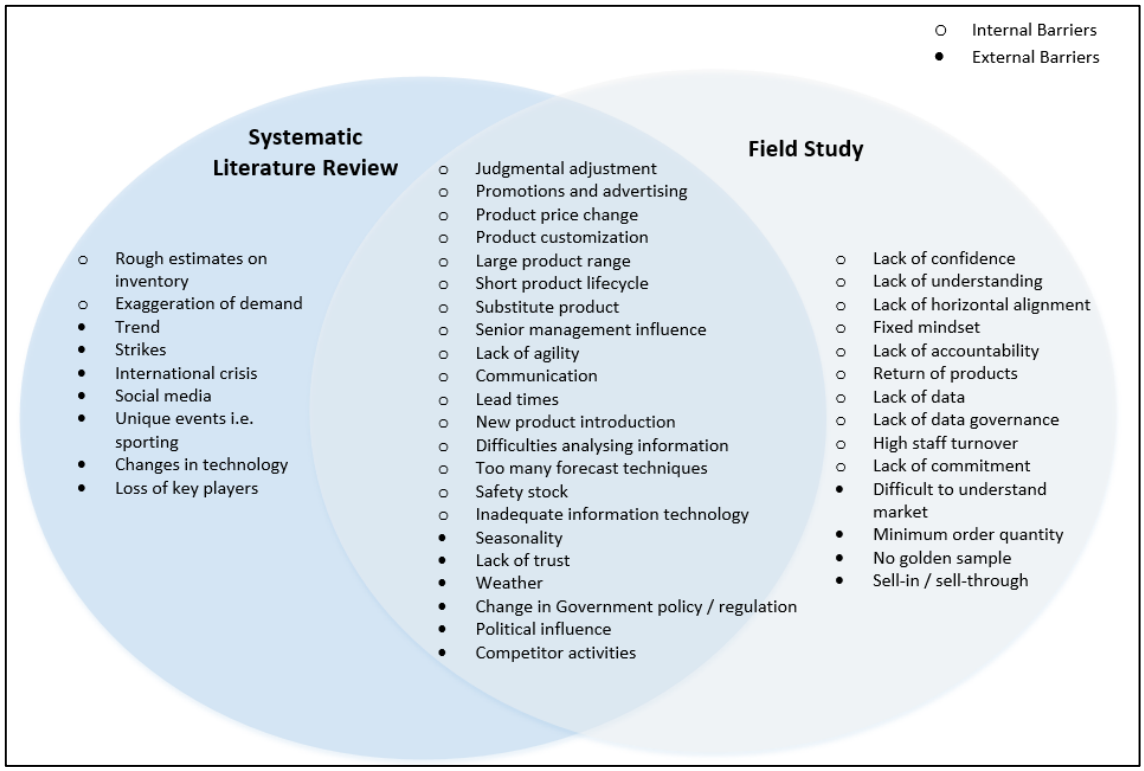

Figure 3 Ven diagram of forecasting barriers from SLR and AEM field study

4.1 Barriers in forecasting uncertain product demand

In summary, six main sources of forecasting uncertain product demand inefficiency were identified. The barriers related to these six themes have been analysed based on the interviewees' answers. Figure 3 demonstrates the results from the comparison of the findings from the SLR and the interviews that highlight the current research and industrial practice gap.

The systematic literature review covers different industries where the interview study is from the Australian electrical industry. AEM field study includes most of the barriers identified from the research literature. Out of 31 barriers provided by the research community, we have mapped 22 of those in our interview study and created an additional 14 barriers which were not present in our SLR. Many of the barriers from the interview study originate as internal organisational barriers.

5. Discussion

This study set out to uncover and investigate the barriers faced in forecasting uncertain product demand in the context of a large electrical manufacturer in Australia (i.e Sydney) from the SC perspective.

We found that the barriers uncovered by many SCs in emerging markets such as Australia are divided into two categories, which are internal to the individual organisation and at the external level. Although there is a wealth of research exploring forecasting in the supply chain, few studies have been reported in the literature, which adopts a focused approach on end to end barriers in forecasting demand and as a cross-case comparative analysis. While these barriers may appear trivial when stated in an article, they often become the major roadblock to successful applications of forecasting demand

These findings are new and different from the barriers found by past studies Table 2. However, they are context-specific and like past studies conducted in specific domains. Thus in line with uncovering the barriers in forecasting uncertain product demand, we were able to uncover the barriers faced in an electrical manufacturer in Australia.

5.1 Driving barriers of forecasting uncertain product demand

Our findings provides insights into the barriers faced in forecasting uncertain product demand from the industry's perspective. These barriers are intertwined and may affect each other.

For cultural barriers our findings lay emphasis on the lack of commitment and horizontal alignment within an organisation. Our research shows that people and their behaviour influences the accuracy of forecasting uncertain product demand. Some cultural forces for example include differences in social patterns, cultural nuances can make the setting up of forecasting information system quite arduous. These cultural differences leads organisations into a lack of corporation and commitment resulting in poor forecasting.

The effect of cultural barriers is evident in past studies [46] stressed that variations in cultural practices can cause errors in the communications between the various nodes in a supply chain. We found that barriers related to culture play a major role in the effectiveness of collaboration and horizontal alignment amongst SC stakeholders. Thus, this barrier is intertwined with communication failure which has proved to be difficult to achieve due to the barriers we found in the organisation, the lack of understanding among SC stakeholder and ineffective communication amongst departments in the organisation.

These cultural barriers are common in SC and have proved to be difficult to improve, as it remains an elusive goal [35, 40, 47-49]. We found that typically these barriers caused neither alignment in the SC which consequently resulted in departments across the organisation working to different demands. This is in line with the findings identified by [50] where there was evidence that forecasts produced by downstream partners and transmitted upstream, were systematically ignored by upstream recipients, thus representing a complete waste of time and effort. Introducing performance measures for SC staff and investment in training to improve relationship management approaches is required to improve the value of collaboration (from an interpersonal perspective), as this would have a positive impact on the SC culture.

For rapid change in product theme it was found that due to rapid advances in technology the electronics products are changing more frequently hence short product lifecycles is a barrier experienced in the organisation. Other studies [51] argue that demand forecast uncertainty decreases with product maturity because demand is supposed to stabilize over time. However, increasingly short life cycles challenge this. Thus, identifying the exact point of maturity for a product to have an impact on stabilisation of the demand is a question that requires further deliberation.

In relation to the market competiveness the results of our study highlights the importance of market intelligence and how a rapid change in product lifecycle weights significantly on the ability to understand the market. Some of the difficulties in understanding the market are similar to those identified in a toy manufacturing markets [52]. However, our research found that the rapid change in technology and intense competition are dominant in allowing SC stakeholders understand the market. This may be due to the uniqueness of the environment the organisation is in. Despite the advantages shown in Flint [45] research that organisations that have a market orientation are better focused on gathering, disseminating, and responding to market than those that are not which enhances the effectiveness of their marketing strategies. [40] study found that new products or products that are sold larger volumes and at lower prices, might not benefit because other factors such as price and competitors' actions could condition the demand forecasting accuracy. These barriers are in line with the findings of [52] who found innovativeness and creativity in toys are critical because most new toys fail and furthermore are challenged in the market by the competitiveness [53].

Our findings indicate that the environment theme is a general problem with most organisations SC, which affects uncertain product demand forecasting due to the created volatility from seasonal variables and also at times very short and specific selling-windows [54].

For the inadequate information technology theme, our findings indicate that inadequate information systems, lack of data governance and a lack of data are barriers in forecasting uncertain product demand. These barriers are important as many organisations require adequate information systems and quality data to operate effectively and efficiently. This insight adds to the debate in the literature [50], regarding the accuracy, availability and consistency of data, proliferation of forecasts, problems with sharing consumer demand data, timeliness of orders, and disconnect between primary production and final consumption. Fragmented IT resources require manual intervention that in turn introduces errors in the which degrades the data integrity [55]. Hence information systems are found to be untrustworthy (Marsh and Flanagan, 2000) and over complex either

internally within organisations or externally in transferring data between organisations. This complexity had typically arisen because systems had evolved rather than having been planned and because of a proliferation of computer and manual systems that had been developed in isolation along the supply chain. [50]. It is evident that these driving forces are SC barriers which are common to organisations who are forecasting demand. The support and investment in information systems and information technology infrastructure are crucial to the success of forecasting uncertain product demand.

6. Conclusions

This study contributes to the literature by expanding the current knowledge about the barriers faced in forecasting uncertain product demand in SC. This research provides valuable contributions to the SC literature by offering rare empirical evidence on the barriers that may arise and impact the forecasting of uncertain product demand between end to end supply chain stakeholders. This exploratory research adds to the literature by highlighting the 31 barriers covered in the systematic literature review, 22 have been identified in our study. Furthermore, an additional 14 barriers have been identified in this field study. All these are considered forecasting uncertain product demand barriers present in the Australian Electrical Manufacture.

The number of interview participants that reflected a barrier in forecasting product demand was highest among the cultural barriers followed by rapid change in product, inadequate information technology and communication failure. These new perspectives contribute to the findings of past studies regarding the complexity of collaboration in SC networks [32, 40, 56]. Similarly, the findings contribute to previous studies [12, 57].

In addition, analysis of qualitative empirical data suggests that the themes and barriers are closely intertwined. Thus, our study supplements the inadequacy of research on SC barriers in forecasting uncertain product demand. Moreover, our research elaborates the findings of the barriers faced and how they influence inadequate forecasts in SCs.

Overall this study's identified six key areas of intervention that is in need of attention with forecasting uncertain demand. The findings of this research can potentially be used to understand the extent of barriers organisations face in forecasting uncertain product demand. This knowledge is valuable for organisations looking at improving their forecasting of uncertain product demand.

This research forms part of our overall project to develop software-supported solutions that address the organisation's highest priority barriers in forecasting uncertain product demand. Our objective is to improve forecasting of uncertain product demand by developing a software-supported solution. This will help the supply chain research community recognize, appreciate and provide solutions to the 'real' industry problems, rather than working on research artifacts such as forecasting techniques without real industrial consideration, evaluation and feedback. The theoretical perspective of this study also generates another avenue of future research, which would be to identify innovative approaches that could be implemented to enhance the forecasting of uncertain demand.

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