The gamification of inventory management in South African petrochemical refineries

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ABSTRACT

Supply chain inventory is a major source of cost, which is why inventory management is a critical focus area for companies. Lean inventory management is the combination of lean and inventory management practices to optimise between inventory cost and customer value. Lean inventory management is enabled by an engaged and empowered workforce. Gamification is the use of game design elements in non-game contexts as a means to improving human engagement and productivity. Combining gamification with lean inventory management is proposed as a method to improve the inventory performance of a company, by improving workforce engagement and productivity.

This quantitative research examined the gamification of supply chain inventory management in lean South African (SA) located petrochemical companies. A model linking the quantifiable barriers which can impact the adoption and implementation of gamified lean inventory management was conceptualised. Applying this conceptual model, an online survey was developed and e-mailed to gather data from 62 respondents representing 5 major SA located petrochemical companies to enable formal hypothesis testing. The results suggest that lean management is a prerequisite for successful gamification and that inventory performance is improved by the adoption and implementation of gamified lean inventory management. Training of employees is recommended as a key intervention to overcome the main barrier to adoption and implementation. This research contributes to knowledge by generating practice insights into lean inventory management and gamification. Furthermore, the study advances the theoretical agenda of determining the pre-determinants of gamification success and whether lean management is a prerequisite for adopting digital tools. In future, it is recommended that research considers the effect of the external environment and individual player types on adoption and implementation.

KEY WORDS

Gamification, Gamify, Lean management, Inventory management

DECLARATION

I, Melisizwe Mashinini, declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in partial fulfilment of the requirements for the degree of Master of Management in the field of Digital Business at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Name: Melisizwe Mashinini Signature:

Signed at JOHANNESBURG

On the THIRTEENTH day of SEPTEMBER 2020

DEDICATION

This dissertation is dedicated to my wife Reneilwe Mashinini, our first born Melokuhle Mashinini and our future children and grandchildren. The world is yours.

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The author wants to thank his wife and daughter for their support and Mthandeni Langa for his perfectionism and guidance

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CHIETA – Chemical Sector Education and Training Authority

EOQ – Economic Order Quantity

GDP – Gross Domestic Product

IDEF0 – Integrated definition for functional modelling

NQF – National Qualifications Framework

PESTEL – Political, Economic, Social, Technology, Environmental and Legal

POLC – Planning, Organizing, Leading and Controlling

SCM – Supply Chain Management

SKU – Stock Keeping Unit

CHAPTER 1. INTRODUCTION

1.1 Purpose of the study

Supply chain inventory management is the planning, organisation, leadership and control of the flow of goods, by-products and related information from origin to consumption Singh and Verma (2018). Inventory management is a critical business function (Fiestras-Janeiro, García-Jurado, Meca, & Mosquera, 2011) as inventory is a major source of cost to companies (Williams & Tokar, 2008). Adopting digital technologies can optimise inventory (Mayr et al., 2018), improving the financial position of firms (Demeter & Matyusz, 2011).

Lean management is a complex, practice based managerial approach to process improvement (Bortolotti, Boscari, & Danese, 2015). Lean management is widely practiced (Mayr et al., 2018) and effective in optimising inventory management (Eroglu & Hofer, 2011) and companywide operations performance (Bortolotti et al., 2015). Central to lean management's effectiveness is employee and management empowerment (Soliman, Saurin, & Anzanello, 2018), requiring a highly engaged workforce (Schonberger, 2019). Lean inventory management, the combination of lean and inventory management practices, is associated with good inventory performance (Eroglu & Hofer, 2011). Gamification, which is the use of game design elements in non-game contexts (Beck, Chitalia, & Rai, 2019), has been proposed as an effective technique to improve workforce engagement (Robson, Plangger, Kietzmann, McCarthy, & Pitt, 2016). Combining gamification with lean inventory management may improve the inventory performance of a company by improving workforce engagement and productivity.

This quantitative study examines gamification of supply chain inventory management in lean South African (SA) petrochemical companies. Figure 1-1 presents the research boundary and the relationship between the key concepts in this research.

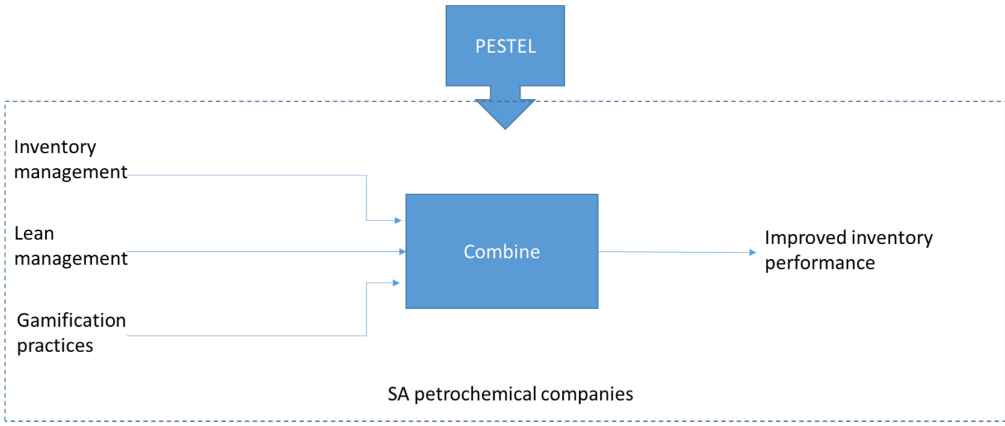

Figure 1-1: High-level conceptual framework

Figure 1-1 shows the high-level conceptual framework of the research: the inventory performance of a firm can be improved through the combination of lean management, inventory management and gamification practices. The focus of the research is the examination of internal factors which enable organisations to digitise their inventory management systems through gamification. An examination of the external political, economic, social, technological, environmental and legal (PESTEL) factors which may compel a firm to digitise their inventory management systems is not a focus of this research.

1.2 Context of the study

The research problem is investigated in the SA context. The SA manufacturing sector is of strategic importance to the SA economy as it contributes 14% to Gross Domestic Product (GDP) and is SA's fourth largest industry (Stats SA, 2019). Manufacturing is one of the key drivers of employment, providing employment for 10% of SA's workforce (Stats SA, 2019). Petrochemicals, defined as chemicals produced from crude oil, coal, gas or gas liquid feed-stocks (Hassani, Silva, & Al Kaabi, 2017), are a significant contributor to the SA manufacturing industry (Stats SA, 2019). The petrochemical sector however, declined 0.9% in 2018 compared to 2017 (Stats SA, 2019) negatively contributing to SA GDP.

The petrochemical sector is a capital intensive industry which is subjected to price volatility, regulation and global competition (CHIETA, 2014). This increases the requirement for digital innovation, where a digital technology is used to augment the sustainability and competitive advantage of a given sector (Hassani et al., 2017). Thus, adoption of digital technology strategies through gamifying inventory management can decrease costs and increase global competitiveness of the SA petrochemical sector. In fact, Schonberger (2019) agrees with Demeter and Matyusz (2011) that optimising inventory management, for instance through gamification, can decrease working capital and improve the financial sustainability of a given firm. Lean practices applied to inventory management have been argued as one of the most effective ways to optimise inventory management (Demeter & Matyusz, 2011). Key to the SA petrochemical sector remaining globally relevant is the adoption of digital technologies to reduce costs and improve financial sustainability. Optimising inventory management through gamification can improve the sustainability and competitiveness of the SA petrochemical sector. The resultant system, transformed through the process of adopting gamification, is referred to as a gamified system.

Inventory performance is conceptualised as a measurable output of an inventory management system. An inventory management system driving a lean optimisation approach may measure inventory performance in terms of inventory days. Inventory days is a widespread inventory performance measure which measures the extent of inventory optimisation in a firm (Demeter & Matyusz, 2011).

1.3 Research problem

Finished goods, work in progress and raw materials inventory management is an important contributor to improving the financial sustainability of a firm. Schonberger (2019), argues that inventory performance has been deteriorating globally since the beginning of the new millennium, negatively impacting financial sustainability of firms. This research primarily aims to elucidate the relationship between inventory performance and gamified lean inventory management systems. Secondary research aims are to identify quantifiable barriers to the adoption and implementation of gamified inventory management systems for improving and sustaining inventory performance of the SA petrochemical sector.

1.4 Research objectives

The research objectives are intended to address the research problem and generate practice insights on lean inventory management and gamification to:

1. Elucidate the relationship between lean inventory management and gamification in SA based petrochemical companies
2. Determine the link between gamified lean inventory management systems and inventory performance (measured as inventory days) in SA based petrochemical companies
3. Identify the quantifiable barriers to adopting and implementing gamified lean inventory management systems in SA based petrochemical companies

1.5 Significance of the study

Inventory management became a critical business function for controlling cost as manufacturing industries grew rapidly from the 20th century (Fiestras-Janeiro et al., 2011). Reducing supply chain inventory by adopting digital technologies (Mayr et al., 2018) can improve the South African petrochemical sector's global competitiveness, increasing contribution to GDP.

The prevalence of gamification in SA petrochemical companies and the understanding of its barriers to adoption may be of benefit to respective stakeholders. Stakeholders include inventory managers, supply chain practitioners and operations managers who may benefit from understanding levers to improve inventory management performance. These identified stakeholders are the audience for this research. This research may contribute to closing the theoretical agenda gap of identifying the pre-determinant requirements for gamification success (Koivisto & Hamari, 2019) and generating lean practice insights. The high rate of unemployment and low country skills base in SA may make the findings of this research useful for other developing countries or sectors with similar contexts.

1.6 Delimitations of the study

1. The research will exclude small, micro and medium enterprises within the petrochemical sector and focus on large multinational companies
2. The inventory performance of the companies will be aggregated to a group level and excludes individual inventory performance at stock keeping unit (SKU) level
3. Investigating the effect of player type on the adoption and success of gamification of inventory management systems will not be a focus of the research
4. The impact of the PESTEL factors on the prevalence and barriers to adoption of gamification of lean inventory management will not be a focus of the research
5. Determination of ecological and temporal validity
6. Orthogonal contrasts of hypotheses formulated using advanced statistical software

1.7 Definition of terms

1. Gamification is the use of game design elements in non-game contexts (Beck et al., 2019)
2. Lean management is the elimination of waste in the value chain through continuous improvement to ultimately maximise customer satisfaction (Mayr et al., 2018)
3. Inventory management is the planning, organisation, leadership and control of the flow of goods, by-products and related information from origin to consumption (Singh & Verma, 2018)
4. Lean inventory management is the application of lean management practices to optimising inventory

1.8 Assumptions

The assumptions listed are those which potentially have the largest influence on the outcome of the research:

1. Inventory days is a conventional measure of inventory performance
2. There is a significant inverse correlation between inventory days and firm financial performance
3. Lean management is a proven methodology to optimise inventory performance

1.9 Conclusion

The criticality of inventory management as a business function in the SA petrochemical industry, the demonstrated benefits of lean as well as the potential for gamification to enhance workforce engagement has been introduced. A critical literature review of the key concepts of inventory management, lean management and gamification in a supply chain management context will be used to develop a conceptual model and accompanying hypotheses. Subsequently, the research methodology is presented to justify the research approach and statistical methods applied to test the hypotheses. The results obtained and analysed according to the research methodology are then be presented and discussed. Finally, concluding remarks will highlight important findings and provide recommendations for practitioners and academics.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

The review of the literature will broadly cover supply chain management and emphasise nascent perspectives detailing the importance of inventory management in the manufacturing and petrochemical industries. An outline of widespread inventory management models offered in the literature will be evaluated with a specific focus on lean management. The important linkages between human factors and inventory management will be decomposed and contextualised within the South African setting. Gamification will be interrogated as a concept for improving employee and stakeholder engagement. The literature review concludes with a strategic analysis indicating how this research may contribute to knowledge in the areas of gamification and lean inventory management. The subsequent chapter draws from the conceptual framework (Figure 1-1) to integrate the critically reviewed theories and models into a comprehensive conceptual model for generating hypotheses. The relationship and integration of key literature findings to generate hypotheses is detailed in Chapter 3.

2.2 Background

Effectively implemented Supply Chain Management (SCM) can improve firm performance, enhancing competitive advantage (Sweeney, Grant, & Mangan, 2015). The end-to-end integration of data and processes is the core of supply chain management (Sweeney et al., 2015) with its purpose being the lifecycle management of materials and information (Reddy, Rao, & Krishnanand, 2019). This broad purpose includes activities such as optimising procurement, transportation and inventory management (Singh & Verma, 2018).

Integration and collaboration present both a challenge and opportunity for supply chains. The opportunity is to improve transparency and efficiency through advances such as digital twin simulations (Mayr et al., 2018). The main challenges relate to the sophisticated information technology capabilities and infrastructure required to support digitalisation (Kache & Seuring, 2017). Furthermore, a large effort is required to ensure integration and backwards compatibility with existing infrastructure for transitional business continuity (Kache & Seuring, 2017).

Lean management is a business management philosophy which integrates business objectives with customer focus through the identification and elimination of waste (Kadarova & Demecko, 2016) and is one of the most widely adopted management philosophies in industry (Mayr et al., 2018). Inventory management is an important component of managing supply chain flows as inventory is the link buffering uncertainty between the performance of production, transportation and customers' demand (Balfaqih, Nopiah, Saibani, & Al-Nory, 2016). One of the central requirements of lean is an engaged and empowered workforce (AlManei, Salonitis, & Tsinopoulos, 2018). Gamification has been proposed as a solution to improving employee engagement using game design elements in non-game contexts, stimulating intrinsic motivation (Mitchell, Schuster, & Jin, 2018). Figure 2-1 assists in extending the conceptual framework for the research.

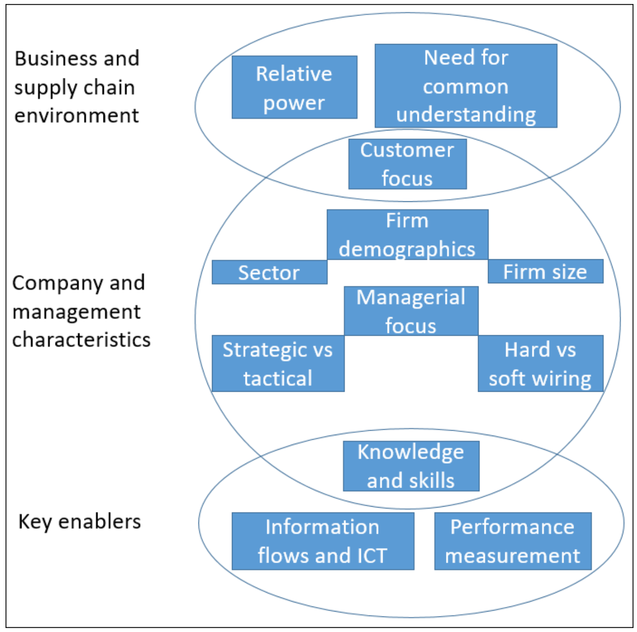

Figure 2-1: Critical success factors and/ or barriers to SCM success adapted from (Sweeney et al., 2015, p. 67)

From Figure 2-1, the key enablers and company and management characteristics can be viewed as enabling mechanisms for successful SCM. The business and supply chain environment can be viewed as the external PESTEL factors which impact SCM. Unpacking perspectives on lean management will contribute to developing a conceptual model which aids in identifying the determinants for successful digitisation (Mayr et al., 2018).

2.3 Lean inventory management

2.3.1 *Lean management*

Lean is an operations management approach which focuses on the elimination of waste (Kadarova & Demecko, 2016) to improve firm performance (Eroglu & Hofer, 2011) by maximising customer value (Alefari, Salonitis, & Xu, 2017). Waste is defined as any resource which adds no value to the end-customer and includes inventory (Kadarova & Demecko, 2016). Lean management practices are applicable even in traditional operations designed to maximise economies of scale, when supported by the adoption of new technologies (Arnheiter & Maleyeff, 2005). Lean management is widely used in various industries (Mayr et al., 2018).

There are several practices which form part of lean management, central to which workforce involvement is required for efficient operations (Demeter & Matyusz, 2011). The lean supply chain (Soliman et al., 2018) and the importance of employee involvement, engagement and commitment (AlManei et al., 2018) are two practices which are of relevance to this research. According to Mayr et al. (2018), the adoption of digitalisation technologies can impact the success of lean by contributing to:

1. Improved workforce engagement
2. Technologies that will improve preventative maintenance
3. Automation, and enhanced decision making using big data analytics

Seminal work authored by Bortolotti et al. (2015), concludes that developing a conducive organisational culture and adopting human resource management practices is fundamental for the successful implementation of lean management. Arnheiter and Maleyeff (2005), argue in their seminal work that organisational culture and empowerment, as well as the training and education of employees and managers are important factors for the effective implementation of lean management.

Urban (2015), argues that lean management is considered the most effective productivity improvement methodology regardless of type of industry. Alefari et al. (2017), cite multiple literature sources in concluding that senior/ top management support is crucial for the success of lean management programmes. This support is demonstrated by senior management articulating and communicating a compelling vision, providing strategic leadership and committing financial resources to the transformation (Alefari et al., 2017).

Lean management has been argued as a prerequisite for implementing Industry 4.0 tools and practices as automating inefficient processes will magnify inherent inefficiencies (Mayr et al., 2018). Another perspective offered is that Industry 4.0 will enhance lean management by introducing flexibility to deal with increasing complexity and can even assist in overcoming lean implementation barriers (Mayr et al., 2018). Lean management and Industry 4.0 both emphasise the crucial role of employee involvement for success (Mayr et al., 2018). Figure 2-2 shows the drivers and barriers to successfully implementing lean manufacturing in companies.

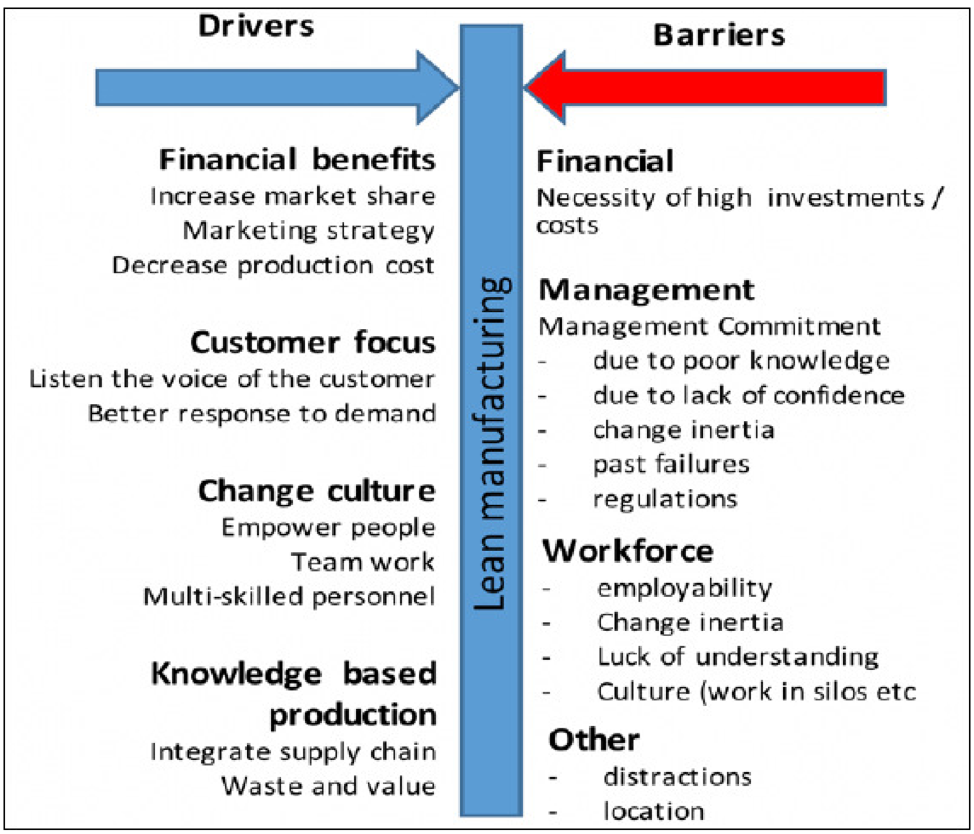

Figure 2-2: Drivers and barriers of lean implementation (AlManei et al., 2018, p. 1161)

The drivers for change are mostly external while the barriers to change are largely constraints which are internal to the firm. The organisational management's capability for managing change is an important determinant of the success of adopting and implementing lean management (AlManei et al., 2018).

Lean management has been criticised by Schonberger (2019) for decreased effectiveness, evidenced by decreasing inventory performance from years 2000 to 2017. Organisations reach diminishing returns as the maturity of their lean management program increases (Arnheiter & Maleyeff, 2005). However, according to Mayr et al. (2018), adopting digital Industry 4.0 tools and practices can further the returns of lean management. This suggests that initiatives, such as adopting digital technologies, can contribute to increasing the rate of return of lean management in organisations where lean management is already mature. The next section details various inventory management models in use and contributes to extending the potential benefits and challenges of applying lean practices to inventory management.

2.3.2 ***Inventory management***

The cost of holding inventory in the United States amounts to approximately US$330 billion (Williams & Tokar, 2008) which is why inventory management is a critical focus area for businesses. Paul, Sarker, and Essam (2016) agree with Williams and Tokar (2008) that the main purpose of inventory is to buffer supply and demand processes, which increases equipment utilisation while ensuring uninterrupted supply to customers. According to Williams and Tokar (2008), incorporating human factors into inventory management would likely significantly contribute to improving the control of inventory. Adoption of digital technologies provides practitioners with additional information which can be used to improve decision making (Williams & Tokar, 2008). According to Mayr et al. (2018), applying Industry 4.0 tools to inventory management can reduce inventory and save cost.

Inventory management approaches can broadly be categorised as traditional or collaborative models/ methods (Williams & Tokar, 2008). Traditional models include the economic order quantity (EOQ) and the periodic review control systems. The traditional models focus on internal coordination of inventory management activities. Collaborative models focus on internal and external coordination of inventory management activities, including concepts such as vendor managed inventory, where the vendor makes the decision on inventory replenishment (Williams & Tokar, 2008). The success of collaborative models has been limited by the lack of business processes which integrate information to improve decision making (Williams & Tokar, 2008). Gamification may be used to improve business processes which integrate information for decision making by contributing to a more engaged collaborative effort (Mayr et al., 2018).

Manufacturing resource planning (MRP) is the most widely used traditional planning method globally (Miclo, Fontanili, Lauras, Lamothe, & Milian, 2016). MRP is composed of a variety of interlinked processes and requires accurate demand forecasts to align all manufacturing activities to push production (Miclo et al., 2016). The major drawback with MRP is the variability of demand forecasts which can create significant supply chain inefficiencies further up the value chain (Miclo et al., 2016). Pull systems aim to reduce variability and the reliance of accurate demand forecasts by producing only what is needed when required, reducing inventory (Schonberger, 2019).

The theory of constraints approach focuses on increasing profit by maximising throughput, while lean focuses on maximising customer value (Slack, Brandon-Jones, & Johnston, 2013). The theory of constraints model can be useful in situations where demand is unconstrained and thus throughput needs to be maximised to meet demand (Şimşit, Günay, & Vayvay, 2014). Slack et al. (2013) clarify that simple systems are suited to approaches such as Just-In-Time (JIT) while more complex systems require rigorous mathematical techniques such as program evaluation and review technique (PERT). This suggests that the choice of inventory management tools is linked to the complexity of the system. The complexity of the inventory management tools in use may be a barrier to the adoption and implementation of digital technologies.

Elucidating the link between inventory performance and lean inventory management, whether gamified or “ungamified”, requires measurement proxies. According to Eroglu and Hofer (2011), multiple studies have applied measurement proxies to measure inventory performance/ leanness. These measures can be classified as absolute, standardized and complex measures (Eroglu & Hofer, 2011). Absolute measures of inventory can be misleading as they are difficult to compare due to differences in industry norms and underlying supply chain structures. Inventory days, a standardized measure, is one of the most widely used measures of inventory leanness and a marker of world-class manufacturing (Demeter & Matyusz, 2011), but does not cater well for the effect of scale economies (Eroglu & Hofer, 2011). The complex measures require expertise in solving and interpreting and are not suitable for widespread managerial use (Eroglu & Hofer, 2011), particularly in developing countries such as SA which have a low skill base (CHIETA, 2014).

Eroglu and Hofer (2011), conclude that inventory leanness mostly has a positive effect on firm performance with an optimal point beyond which performance deteriorates. Low inventory days results in lower working capital and frees up capital for investments or servicing debt, both which are improvement levers for the financial performance of a company (Demeter & Matyusz, 2011). Inventory days was determined to be a more suitable measure of analysis by Demeter and Matyusz (2011), as it is less sensitive to scaling than inventory turnover, resulting in more comparable data.

Barriers to lean management adoption, adapted from Rane, Jadhav, and Mantha (2014) and categorised using the definitions provided by Attri, Grover, and Dev

(2014) are shown in Table 2-1. Logically it can be inferred that these barriers will be common when attempting to gamify inventory management systems using a lean management approach.

Table 2-1: Barriers to implementing lean inventory management adapted from Rane et al. (2014) and Attri et al. (2014)

Human and cultural barriers	Behavioural barriers	Technical barriers	Strategic barriers	Operational barriers
Lack of trust Cultural differences Lack of coordination Management resistance to empowering employees	Employee resistance Lack of perseverance Top/ senior management resistance Lack of cross-functional cooperation Lack of senior management commitment	Lack of training material Lack of training Lack of a sound inventory management system Lack of understanding principles of lean management	Lack of vision and/or strategy Unclear organisational goals and objectives	Misalignment with performance management and incentive system Lack of financial resources Lack of support infrastructure

As presented in Table 2-1 above, barriers can be broadly classified as human and cultural, behavioural, technical, strategic and operational. These barriers can be present in the enabling mechanisms and controls governing the adoption and implementation of lean inventory management.

The conceptual integration of lean management and inventory management forms the foundation of lean inventory management. The following are practices, supported by Soliman et al. (2018), which are typically present in organisations which have adopted lean inventory management:

1. Inventory is seen as a form of waste which needs to be eliminated
2. Customer value focus drives decision making in the inventory management process
3. Employees are empowered to take decisions to improve inventory performance
4. The organisational culture supports the continuous improvement of inventory performance
5. The goal is the pursuit of perfection of inventory performance
6. The organisation aims to reduce the complexity of the inventory management process
7. Management decisions are based on a long-term strategic focus as opposed to short-term financial performance

Strong agreement to the lean inventory management principles and practices in a company is indicative of the extent of adoption of lean inventory management. By elucidating the link between lean inventory management and gamification, insight may be generated into whether lean is a prerequisite for the adoption of Industry 4.0 tools and practices (Mayr et al., 2018), such as gamification.

2.4 Gamification

2.4.1 *Gamification and Industry 4.0*

The global gamification market is forecast to exceed $19 billion by 2023 (Xi & Hamari, 2019). Employee and customer engagement are of great interest to managers and have been the subject of numerous research articles (Robson et al., 2016). Robson, Plangger, Kietzmann, McCarthy, and Pitt (2015) agree with Deterding, Dixon, Khaled, and Nacke (2011) in defining gamification as the application of game design elements in non-game contexts, in order to improve human engagement and enjoyment (Koivisto & Hamari, 2019). Koivisto and

Hamari (2019) agree with Robson et al. (2015) that a majority of companies will implement gamification in the near future.

Intrinsic motivators for human behaviour, such as flow, immersion, enjoyment, competence and mastery, are commonly experienced when people play games (Koivisto & Hamari, 2019). The enjoyment factor of a gamified process is important in ensuring workplace effectiveness and sustainability (Mitchell et al., 2018). Digital technologies such as sensors and computing technology are key enablers of gamification (Nacke & Deterding, 2017). Gamification research is maturing to focus on the implementation aspects of gamification (Höllig, Tumasjan, & Welpe, 2018).

The effect of organizational context has been one of the least studied aspects of gamification (Warmelink, Koivisto, Mayer, Vesa, & Hamari, 2018). The highly structured, standardized and repetitive nature of operational activities make gamification conceptually appealing based on the possibility of improving employee engagement (Warmelink et al., 2018).

The potential held by gamification lies in reducing complexity by the subdivision of tasks and restructuring them with game elements (Koivisto & Hamari, 2019). The support of a performance management system, a supportive social community or establishment of meaningful narrative is crucial for successful gamification (Koivisto & Hamari, 2019). According to El-Telbany and Elragal (2017), gamification can be viewed as an enhancement to performance management systems through the use of technology to improve data velocity and visibility while increasing enjoyment. Gamification has been used in lean management for engaging teams to broaden their scope in the search for results (Pereira, Oliveira, Vieira, Lima, & Paes, 2018).

Enjoyable use of a system increases the likelihood of sustained long term usage (Koivisto & Hamari, 2019). Competence, autonomy and relatedness are motivational needs commonly satisfied by games (Koivisto & Hamari, 2019). According to Robson et al. (2015), inappropriately gamified processes will result in an estimated 80% of currently gamified applications failing to meet business objectives. Gamification encourages behaviour change through the formation of habits by reinforcing rewards (Robson et al., 2015). Figure 2-3 shows a framework for gamification.

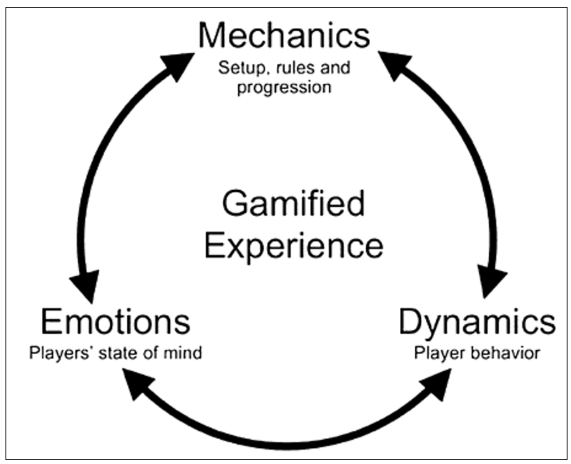

Figure 2-3: The MDE framework for gamification (Robson et al., 2015, p. 416)

As presented in Figure 2-3, the important components for gamification are captured in the mechanics, dynamics and emotions (MDE) framework (El-Telbany & Elragal, 2017). Mechanics refer to the rules, goals and rewards of the game, dynamics refer to how players enact mechanisms, and emotions refer to how players feel about the gamified experience (Robson et al., 2015).

Gamification is applicable and has demonstrated benefits for activities requiring long-term engagement and continuity for sustainable results (Koivisto & Hamari, 2019) and may be a solution to addressing decreasing levels of employee engagement (Mitchell et al., 2018). Lean management requires a culture of long-term commitment and engagement to continuous improvement (Schonberger, 2019) and thus may be boosted by gamification.

Gamification of a process should be driven by clear goals that impact firm performance and can be driven by adjusting human behaviours (Robson et al., 2015). Focusing on one goal minimizes complexity and avoids MDE conflicts (Robson et al., 2015). According to Mitchell et al. (2018), gamification should benefit both employees and the organisation otherwise it can be seen as exploitative (Warmelink et al., 2018). Gamification can be more cost effective than traditional employee engagement initiatives as it can replace monetary incentives with virtual ones (Deterding, 2018). Appropriate metrics are required to support the adoption and implementation of gamification (Robson et al., 2016) as part of an integrated performance management system.

The likelihood that people will want to cheat a gamified process (Robson et al., 2015) should be considered in the design of the system to avoid perception bias which would impact the adoption of the gamified system. Another possible detractor to the adoption of a gamified process is the potential to amplify extrinsic motivation factors such as public embarrassment (Mitchell et al., 2018).

Beck et al. (2019) agrees with Robson et al. (2016) that gamified process have at least one of the following gamification components/ mechanics embedded in the process:

1. Leader boards, badges and points
2. Increasing task difficulty
3. Finite end
4. Multiplayer orientation
5. Infinite play
6. New levels

7. Team playing
8. Online playing
9. Real world playing

The absence of 1 or more of the mechanics reduces the likelihood of being able to engage more employees based on differing intrinsic drivers that employees have. The presence of 1 or more of these mechanics is an indicator of the extent of adoption of gamification. Furthermore, user ratings were found by Beck et al. (2019) to increase with the increased use of gamification mechanics.

The integration of virtualised business procedures and performance indicators linked to incentives is a requirement for successful gamification (Deterding, 2018). In order to interrogate whether a process is ready for gamification, the sophistication of business procedures, performance indicators and incentives must be interrogated. The successful gamification of an inventory management system requires sophisticated business procedures, which can be linked to lean management principles, and a mature performance management system. These business procedures can be viewed as controls while performance management systems can be viewed as enabling mechanisms.

2.4.2 ***Gamification and human factors***

South Africa's reliance on foreign technology and lack of critical professional and artisanal skills (CHIETA, 2014) suggests that the focus should be on process innovation as opposed to technological innovation. According to Pflaum, Bamberg, Prockl, Bodendorf, and Chen (2019), the digital transformation of business models and process must be understood fundamentally as innovation activity.

Gamified processes should support autonomy and needs satisfaction (Mitchell et al., 2018) implying that organisational culture and behaviours which don't encourage employee empowerment will be a barrier to successfully gamified processes. Table 2-2 shows the variables used to predict the intention to use technology.

Table 2-2: Variables used to predict the intention to use a technology (Baptista & Oliveira, 2019, p. 311)

Variable	Description
Ease of use	The degree to which a person believes that using an information system would be free of effort (Davis, 1989)
Learning opportunities	The degree to which a person believes that using an information system can offer him or her opportunities for learning (Bourgonjon et al., 2010)
Socialness	Users' perception of information systems as a social actor (Wakefield et al., 2011)
Hedonic value	Users' perception of fun, pleasure and excitement (Holbrook, 1986)
Usefulness	The degree to which a person believes that using an information system would enhance his or her job performance (Davis, 1989)
Enjoyment	The extent to which the use of the information system is perceived as enjoyable on its own (Davis, 1989)
Brand attitude	Users' perception and evaluation of a branded product (Mitchell & Olson, 1981)
Attitude	Users' overall evaluation of the systems' use, favourable or unfavourable (Ajzen, 1991)
Intention	The degree to which a person has formulated conscious plans to perform or not perform some specific future behaviour (Warshaw & Davis, 1985)

The construct definitions in Table 2-2 can be used to determine the likelihood of adoption of gamified processes. The constructs can be integrated with the human, cultural and employee barriers summarised in Table 2-1 towards a detailed conceptual model related to organisational employee enabling mechanisms.

According to CHIETA (2014), green occupations include jobs which reduce materials and energy required through high efficiency strategies. This definition is conceptually similar to the principle of eliminating waste in lean management. The total number of employees in green occupations is approximately 14500 (CHIETA, 2014). Employees which will likely be most involved in the management of inventory include supply chain professionals, production and sales planners and operations managers. These employees typically are from industrial and chemical engineering occupations, which is a total of approximately 1482 employees (CHIETA, 2014). The population of employees specifically involved in inventory management is estimated at 20% which is 296.

Performance management for an integrated supply chain is required for companies to sustain competitive advantage (Balfaqih et al., 2016) by measuring supply chain efficiency (Reddy et al., 2019). A well-functioning performance management system is an important component as an enabler of gamification, due to the reliance of gamification on real-time performance feedback. A poorly designed performance management system can result in misalignment between operational and strategic goals.

Managing human factors is a key component of successful implementation of lean management (Vukadinovic, Macuzic, Djapan, & Milosevic, 2018). Lean management encompasses technical operational tools and human factors as part of a broader socio-technical system (Vukadinovic et al., 2018). Vukadinovic et al. (2018), assert that the full benefits of lean management will not be achieved without effective employee management and consideration of human factors. The focus on human factors is to better integrate the human-machine interface to improve performance (Vukadinovic et al., 2018).

2.5 Conclusion of Literature Review

According to Lang and Ohana (2012), a trend analysis of the number of publications aiming to address a particular management concept is indicative of the interest in the concept. A publication trend analysis showing quick growth then rapid decline phase can be indicative of a fashionable management concept which may not have long term research relevance. Figure 2-4 shows a trend analysis of lean management using the Scopus online database accessed on 1 July 2019

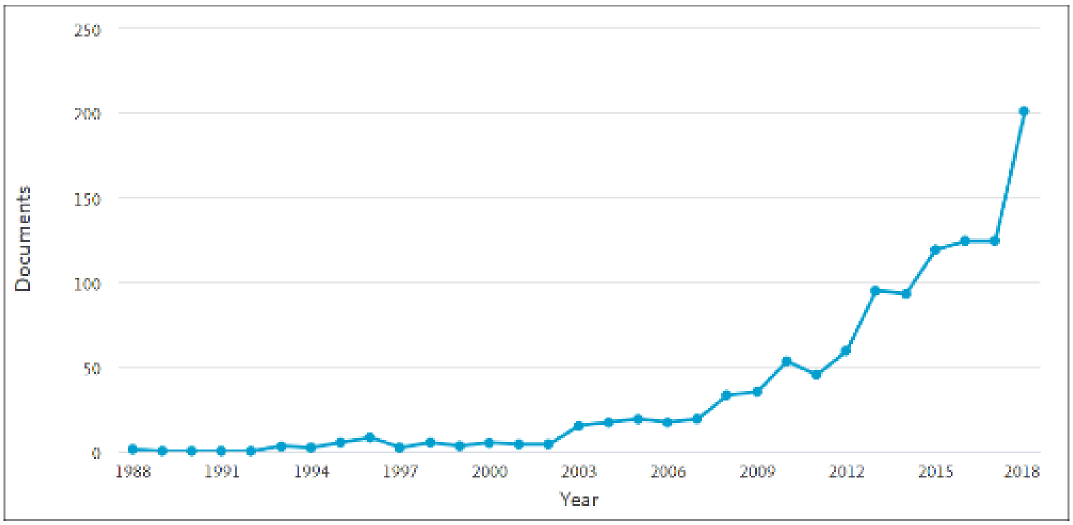

Figure 2-4: Scopus search using the search terms "lean management" © Elsevier B.V.

The Scopus database was used to focus on peer-reviewed literature. From analysing Figure 2-4, lean management has shown exponential growth in research interest spanning two decades. Figure 2-5 shows a trend created based on the results returned from querying the Scopus online database on 30 March 2019. The Scopus database was used to particularly focus on peer-reviewed literature.

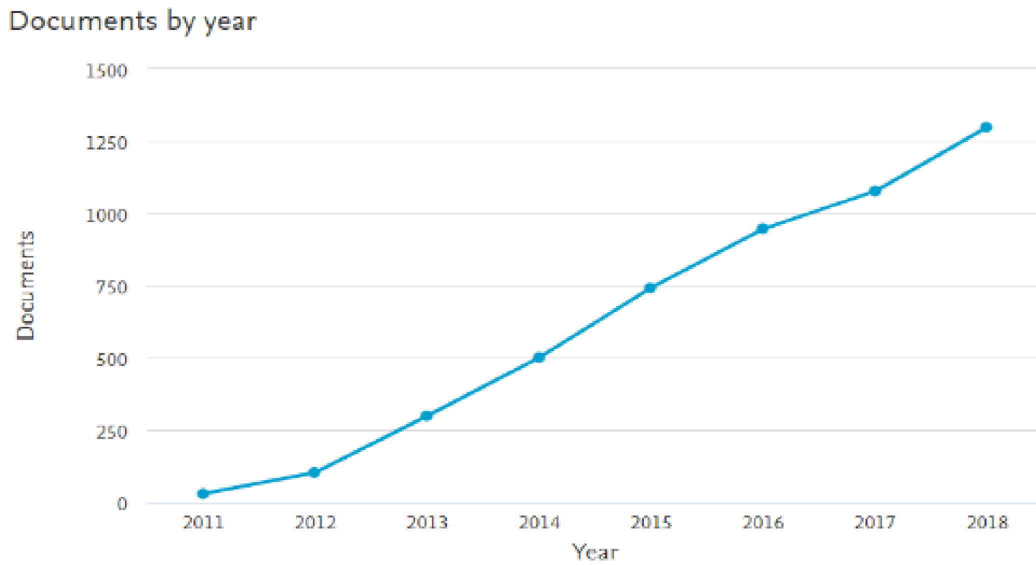

Figure 2-5: Scopus search “gamification” or “gamify” or “gamified” © Elsevier B.V.

From analysing Figure 2-5, the concept of gamification is relatively new, but research interest continues to grow and has not yet shown a decline over 7 years. This shows that the proposed research, combining lean management and gamification, is relevant and will likely continue to be in the future.

Transitioning towards a full automation that requires minimal human intervention requires expensive and sophisticated technology that will likely be financially prohibitive for most companies in developing economies. This suggests that human related factors in inventory management is still an important consideration to decrease supply chain inventory to improve firm competitiveness. Additionally, the lack of highly skilled engineers, artisans and system integrators in SA is a potential barrier to adopting full automation technologies. Gamification may potentially improve inventory performance with accumulative improvements to employee productivity and collaboration. Quantifiable barriers to the process of adopting and implementing gamification of lean inventory management may be preventing SA petrochemical firms from utilising gamification to improve competitiveness.

The Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis is supported by the work of Helms and Nixon (2010), as a planning tool. A SWOT analysis is conducted to identify the opportunities presented by the literature review for further research while being aware of potential issues with methodological fit in order to proactively manage them. Figure 2-6 presents the SWOT analysis arising from the review of the literature.

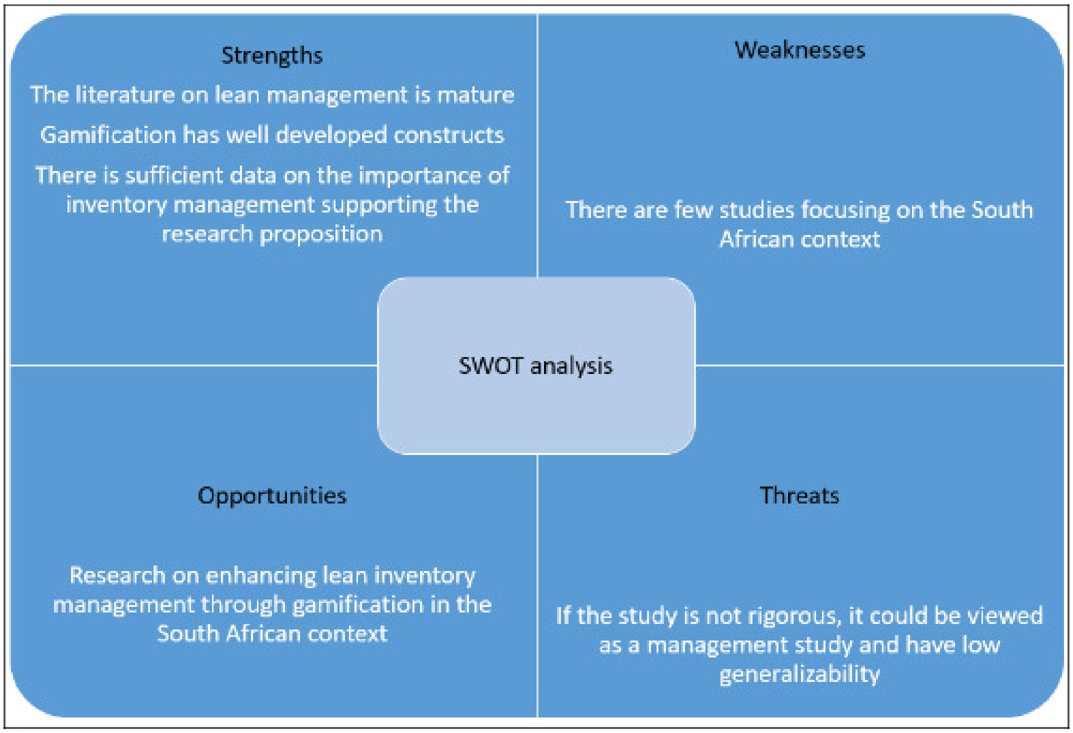

Figure 2-6: SWOT analysis of the proposed research

As presented in Figure 2-6, the prior theory on lean management is mature while the constructs and measures related to gamification are well defined. There is a shortage of literature covering the linkage between gamification and lean inventory management in petrochemical companies operating in developing countries. Furthermore, research addressing the SA context is limited. The potential to contribute to the body of knowledge was based on the identification of this opportunity.

The literature survey provides a research basis by framing the importance of lean and inventory management to firms, the potential of gamification, human factors as well as barriers. This literature survey has enabled the design of a conceptual model that illustrates the relationship and integration of key concepts which will be used to address the research aims.

CHAPTER 3. CONCEPTUAL MODEL

3.1 Introduction

Gamification may improve workforce engagement which in turn makes lean inventory management more effective. A lean approach to inventory management can optimise inventory, reducing working capital and improving firm competitiveness. The conceptual method will integrate the theories and models reviewed in the literature. The linkages between the quantifiable barriers which can impact the prevalence, adoption and implementation of gamified lean inventory management will be proposed in an integrated conceptual model. The integrated conceptual model provides the basis for generating hypotheses towards addressing the research objectives.

3.2 Applicable theories

The key theories underlying the concepts of gamification and lean management are change management theory (AlManei et al., 2018), self-determination theory (Koivisto & Hamari, 2019) and the technology acceptance model (Baptista & Oliveira, 2019). The integration of the applicable theories will be shown using the integrated definition for functional modelling (usually abbreviated as IDEF0) technique/tool. IDEF0 is a well-established systems modelling technique with standardized nomenclature, enabling simple representation of complex systems in any required level of decomposition (Waissi, Demir, Humble, & Lev, 2015). IDEF0 modelling is a powerful technique for visual analysis of activity and information flows (Lukszo, 2009) and is widely used for business systems and process planning (Moreno et al., 2017). Figure 3-1 shows the high-level conceptual model showing the relationships between the concepts.

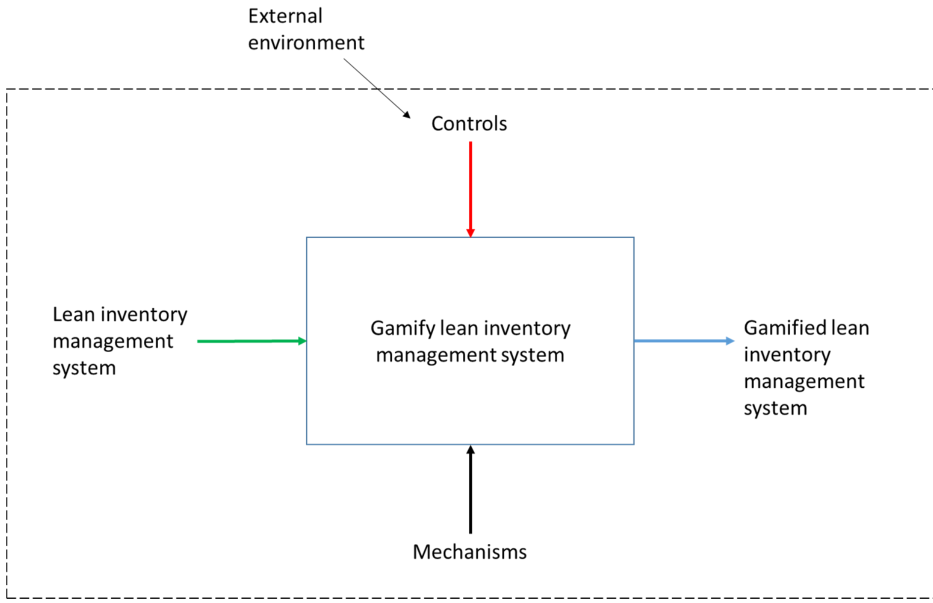

Figure 3-1: High level research conceptual model adapted from Mashinini (2016, p. 26)

Figure 3-1 shows the high-level function of the process, which is to gamify a lean inventory management system. Gamification is defined as the use of game design elements in non-game contexts (Beck et al., 2019). Self-determination is an applicable theory commonly used to understand the motivational potential of games (Koivisto & Hamari, 2019). Supply chain inventory management is the process of optimising the flow of raw materials, finished products and work in process materials in order to optimise firm financial performance and meet customer requirements (Singh & Verma, 2018). Lean is an operations management approach which focuses on the elimination of waste (Kadarova & Demecko, 2016) to improve firm performance (Eroglu & Hofer, 2011) by maximising customer value (Alefari et al., 2017). Inventory days is one of the most widely used performance measures of inventory (Demeter & Matyusz, 2011) and is correlated with improved firm financial performance (Eroglu & Hofer, 2011).

The gamification of lean inventory management is a function which transforms the lean inventory management system of an organisation, into a gamified lean inventory management system, enabled by mechanisms and governed by controls. The gamified lean inventory management system is conceptualised as an improvement to an ungamified lean inventory management. The input to the function is a lean inventory management system, which will be transformed to yield an output of a gamified lean inventory management system. The mechanisms required to complete this function are organisational facilities, such as computer and networking infrastructure, organisational workforce and management. Technology acceptance theory can be used to understand the factors which can predict the adoption of new technology by employees and managers. The management of the transformation process can be linked to change management theory (AlManei et al., 2018). The function is governed by controls, which can be the organisational strategy, industry standards and practices as well as applicable laws and regulations.

The external environment can primarily impact the controls such as organisational strategy and industry standards. External impacts, such as changes in the competitive landscape, can prompt changes in organisational strategy in response. Changes in industry standards can result from the sharing of new best practices learned across industry. Quantifiable barriers to the inputs, controls and mechanisms such as the absence of inventory management in organisational strategy or the lack of inventory measurement devices, can inhibit the adoption and prevalence of the gamification of lean inventory management systems.

3.3 Detailed conceptual model

The high-level conceptual framework is further decomposed in order to enable elucidation of the linkages between the factors identified in Figure 3-1.

3.3.1 *Detailed conceptual model for lean inventory management*

The literature review in the preceding section provides a basis on which to expand the high-level conceptual model represented in Figure 3-1. The approach used by Mashinini (2016), will be used to conceptualise and define the detailed elements which operationalise the functions of adopting and implementing a lean inventory management system. This conceptualisation is done in order to better understand determinants of success and barriers. Adoption is conceptualised to primarily occur at the policy and strategic level supported by top management. Implementation is conceptualised to occur mainly at the tactical and execution level of middle management and frontline workers. Figure 3-2 shows the detailed conceptual model for the adoption and implementation of lean inventory management.

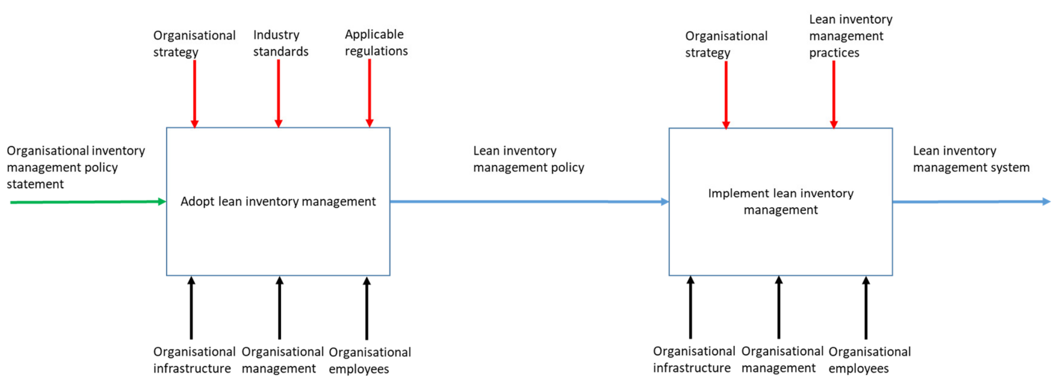

Figure 3-2: A conceptual model for adopting and implementing lean inventory management adapted from Mashinini (2016, p. 26)

A review of the literature has shown the importance of top management support for successfully adopting and implementing lean inventory management (Alefari et al., 2017). The absence of top management support can be viewed as a strategic barrier (Attri et al., 2014). Top management support can be expressed as a policy statement requiring the adoption of lean inventory management in order to improve business performance. From Figure 3-2, this policy statement is the input to the first function, as without policy direction from top management, adoption throughout the firm may be retarded. The function of adopting lean inventory management is governed by controls, namely existing organisation strategy, industry standards and applicable regulations. Lean inventory management must be adopted to complement the overall business strategy (Schonberger, 2019), comply with applicable regulations and adhere to industry standards (Eroglu & Hofer, 2011) to ensure sustainability. Table 3-1 defines the controls required for the adoption of lean management.

Table 3-1: Controls governing the adoption of lean inventory management

Controls		**Basis**	**Description**	**Measurement**
C-1	Organisational strategy	(Alefari et al., 2017) (Rane et al., 2014) (Sweeney et al., 2015) (AlManei et al., 2018)	The organisations long term goals and objectives in pursuit of fulfilling its vision	5-point Likert-type item measuring the extent of agreement
C-2	Industry standards	(Rane et al., 2014) (Alefari et al., 2017) (AlManei et al., 2018) (Eroglu & Hofer, 2011)	The applicable industry standards which provide best practices on lean management principles	5-point Likert-type item measuring the extent of agreement
C-3	Applicable regulations	(Rane et al., 2014) (Sweeney et al., 2015) (AlManei et al., 2018)	The applicable regulations which need to be complied with in order to secure a licence to operate	5-point Likert-type item measuring the extent of agreement

Measurements for the controls governing the adoption of lean inventory management are defined in Table 3-1 above. The three controls identified are further supported by the works of AlManei et al. (2018), Alefari et al. (2017), Sweeney et al. (2015), (Eroglu & Hofer, 2011) and Rane et al. (2014). Collection of Likert-type data will enable elucidation of the extent to which each control is potentially a barrier to the adoption of lean inventory management.

The controls which govern the implementation of lean inventory management are organisational strategy and lean inventory management practices. Organisational strategy was defined in Table 3-1 above (C-1). Lean inventory management practices refer to the specific lean management practices applicable to inventory management. These are practices such as lean supply chain, Just-In-Time and pull production (Alefari et al., 2017) which are practices with the goal of minimizing waste in the form of inventory. The feasibility of implementing lean inventory management practices is also a function of system complexity (Slack et al., 2013). Table 3-2 shows the controls governing the implementation of lean inventory management.

Table 3-2: Controls governing the implementation of lean inventory management

Control		**Basis**	**Description**	**Measurement**
C-4	Lean inventory management practices	(Alefari et al., 2017) (Slack et al., 2013) (Williams & Tokar, 2008) (AlManei et al., 2018) (Mayr et al., 2018)	The feasibility of implementing lean inventory management best practices. Specific practices are identification and elimination of waste, employee empowerment, continuous improvement and customer focus	5-point Likert-type item measuring the extent of agreement summated into a Likert-scale

Control		Basis	Description	Measurement
		(Soliman et al., 2018)		

The measurements for the unique control governing the implementation of lean inventory management is defined in Table 3-2 above. The identified control is supported by the works of AlManei et al. (2018), Alefari et al. (2017), Slack et al. (2013) and Williams and Tokar (2008). Collection of Likert-type data will enable quantification of the extent to which this control is potentially an implementation barrier to lean inventory management. Lean management practices will focus on the identification and elimination of waste, employee empowerment, continuous improvement and customer focus (Mayr et al., 2018). Tables 3-3 to 3-5 decompose the functional mechanisms for adopting and implementing lean inventory management.

Table 3-3: Organisational management mechanisms for adopting and implementing lean inventory management

Mechanism: Organisational management		Basis	Description	Measurement
M-1	Human resource management	(Rane et al., 2014) (Alefari et al., 2017) (AlManei et al., 2018) (Sweeney et al., 2015) (Urban, 2015)	The extent to which planning, organisation, leading and controlling (POLC) of employees enables lean inventory management	5-point Likert-type item measuring the extent of agreement

Mechanism: Organisational management		Basis	Description	Measurement
		(Bortolotti et al., 2015)		
M-2	Management focus	(Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017) (AlManei et al., 2018) (Soliman et al., 2018)	The extent to which management has a strategic versus tactical focus	5-point Likert-type item measuring the extent of agreement
M-3	Change management	(Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017) (AlManei et al., 2018)	The extent of competence in POLC of business transformations enables lean inventory management	5-point Likert-type item measuring the extent of agreement
M-4	Lean inventory management	(Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017)	The extent of competence in POLC the process of optimising the flow of raw materials, finished products and work in process materials in order	5-point Likert-type item measuring the extent of agreement

Mechanism: Organisational management		Basis	Description	Measurement
		(AlManei et al., 2018) (Bortolotti et al., 2015)	to minimize waste while meeting customer requirements	

Table 3-3 presents the main mechanisms related to organisational management impacting on the success of adopting and implementing lean inventory management programs. Management competence in managing human resources and change management is required to enable employee engagement, overcome change inertia and ensure the correct balance between tactical and strategic actions (Alefari et al., 2017). Change management is derived from Lewin's fundamental three step model (Cummings, Bridgman, & Brown, 2015). Competence in managing a lean inventory organisation is also a requirement to ensure the principles of lean which govern the process, are correctly operationalised to support organisational strategy within the confines of applicable regulations (AlManei et al., 2018). Table 3-4 focuses on the mechanisms specific to organisational employees.

Table 3-4: Organisational employee mechanisms for adopting and implementing lean inventory management

Mechanism: Organisational employees		Basis	Description	Measurement
M-5	Employee resistance	(Rane et al., 2014) (Alefari et al., 2017)	The extent to which an employee displays inertia to change	5-point Likert-type item measuring the extent of agreement

Mechanism: Organisational employees		Basis	Description	Measurement
		(AlManei et al., 2018)		
M-6	Employee training	(Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017) (AlManei et al., 2018)	The perceived value and number of training interventions completed with the aim of improving the efficiency and effectiveness of lean inventory management	5-point Likert-type item measuring the extent of agreement

High levels of employee resistance will likely require high levels of change management competence to overcome, requiring a large organisational investment (AlManei et al., 2018). The continuous improvement philosophy of lean inventory management requires well-trained employees that are up to date with the state-of-the art in lean inventory management practices (Alefari et al., 2017). The perceived value and number of training interventions is a proxy to understanding how supportive employee training is to adopting and implementing lean inventory management. Table 3-5 details the organisational infrastructure mechanisms.

Table 3-5: Organisational infrastructure mechanisms for the adoption and implementation of lean inventory management

Mechanism: Organisational infrastructure		Basis	Description	Measurement
M-8	Software and computer infrastructure	(Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017) (Slack et al., 2013)	Computer software and systems enabling the management of the lean inventory management	5-point Likert-type item measuring the extent of agreement
M-9	Hardware and facilities	(Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017)	The physical tools, facilities and environmental layout of the equipment which impact on employees' ease of executing lean inventory management	5-point Likert-type item measuring the extent of agreement

Computer and software are required for tracking the performance of the inventory management system efficiently (El-Telbany & Elragal, 2017). Hardware and facilities relate to the physical tools required for lean inventory management (Mayr et al., 2018).

The output of the function to adopt lean inventory management is a policy, which is the input to implementing lean inventory management. The absence of a policy will be a barrier to the implementation of lean inventory management. The output of the function to implement lean inventory management is an implemented lean inventory management system, which is integrated with the business to meet strategic objectives, strives towards meeting best practices, and complies with applicable regulations. Table 3-6 shows the overall output from the adoption and implementation of lean inventory management, a measure of inventory leanness.

Table 3-6: Overall functional output for adopting and implementing lean inventory management

Output		**Basis**	**Description**	**Measurement**
O-1	Inventory leanness	(Eroglu & Hofer, 2011) (Demeter & Matyusz, 2011)	The days of inventory of finished goods held by the firm	A continuous scale measured in days.

The overall measure for the success of the functions is inventory leanness (Eroglu & Hofer, 2011), which can be approximated by inventory days (Demeter & Matyusz, 2011). This measurement proxy was chosen as it is simple and doesn't require advanced expertise (Eroglu & Hofer, 2011) which may not be available to companies based in developing countries such as SA (CHIETA, 2014). A well-functioning lean inventory management system will maximize inventory leanness while ensuring that no additional waste is created, such as product stock-outs, poor quality or late deliveries.

3.3.2 ***Hypotheses***

Hypotheses have been formulated based on the literature review and detailed conceptual model represented in Figure 3-2 and decomposed in Tables 3-1 to 3-6.

Null Hypothesis H0-1: Firms which have adopted and implemented lean inventory management have no difference in inventory days in comparison to firms which have not adopted lean inventory management

Alternate Hypothesis H-1: Firms which have adopted and implemented lean inventory management have a difference in inventory days in comparison to firms which have not adopted lean inventory management

Null Hypothesis H0-2: Organisational management is not a barrier to the adoption and implementation of lean inventory management

Alternate Hypothesis H-2: Organisational management is a barrier to the adoption and implementation of lean inventory management

The above hypotheses will assist in elucidating the link between the concepts represented in Figure 3-2.

3.3.3 *Detailed conceptual model for the gamification of lean inventory management*

The literature review on gamification in the preceding section provides a basis on which to expand the detailed conceptual model represented in Figure 3-2. The approach used by Mashinini (2016, p. 26), will be used to conceptualise and define the detail elements which operationalise the functions of adopting and implementing a gamified lean inventory management system in order to better understand determinants of success and barriers. Figure 3-3 presents the detailed conceptual model for adopting and implementing a gamified lean inventory management system.

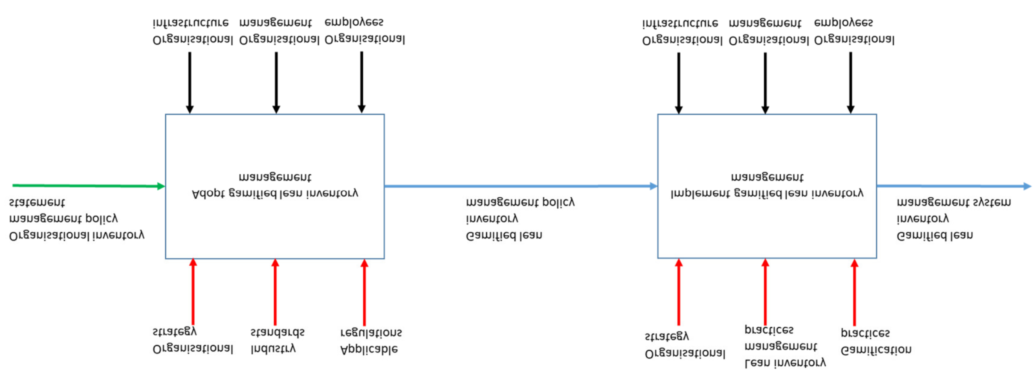

Figure 3-3: The conceptual model for the adoption and implementation of gamified lean inventory management adapted from Mashinini (2016, p. 26)

Figure 3-3 extends the conceptual model represented in Figure 3-2 using the approach from Mashinini (2016), by integrating the concept of gamification with lean inventory management. The addition of gamification results in the addition of functional controls and mechanisms which are required to govern and enable the processes with the overall output of improving inventory performance. The additional controls and mechanisms required will be defined in Tables 3-7 to 3-10.

Table 3-7: Additional controls governing the adoption and implementation of gamified lean inventory management

Controls		**Source**	**Definition**	**Measurement**
C-5	Gamification practices	(Robson et al., 2016) (Robson et al., 2015) (El-Telbany & Elragal, 2017) (Beck et al., 2019)	The number of the 9-gamification mechanics implemented	10-point dichotomous matrix scale

Table 3-7 defines the additional controls required for gamifying a lean inventory management system. The addition of gamification practices as a control in the implementation of gamification of lean inventory management relates to the feasibility of integrating the 9 gamification mechanics (Robson et al., 2016) to the existing lean inventory management system within the MDE framework (El-Telbany & Elragal, 2017). According to Beck et al. (2019) the number of gamification mechanics which are implemented can be used as a measure of the extent of implementation. Table 3-8 shows the mechanisms for organisational management that are additionally required.

Table 3-8: Additional organisational management mechanisms for the adoption and implementation of gamified lean inventory management

Mechanism: Organisational management		Basis	Description	Measurement
M-10	Human-machine interface management	(Vukadinovic et al., 2018)	The extent which management has competence in POLC of human-machine interfaces enables gamified lean inventory management	5-point Likert-type item measuring the extent of agreement
M-11	Digital transformation management	(Pflaum et al., 2019)	The extent to which management has the competence to POLC digital transformations	5-point Likert-type item measuring the extent of agreement

Table 3-8 presents the main mechanisms related to organisational management that are required additionally for the adoption and implementation lean inventory management programs. Management competence in managing human-machine interfaces (Vukadinovic et al., 2018) and digital transformations (Pflaum et al., 2019) is required to enable the success of gamification by ensuring the gamified system integrates well with employees and existing organisational infrastructure. Table 3-9 shows the additional organisational employee mechanisms required.

Table 3-9: Additional organisational employee mechanisms for the adoption and implementation of gamified lean inventory management

Mechanism: Organisational employees		Basis	Description	Measurement
M-12	Employee education level	(CHIETA, 2014) (García, Pedreira, Piattini, Cerdeira-Pena, & Penabad, 2017)	The education level of an employee based on the SA NQF level	5-point Likert-type item measuring the extent of agreement
M-13	Employee motivation	(Koivisto & Hamari, 2019) (Sweeney et al., 2015) (AlManei et al., 2018) (Mitchell et al., 2018) (Baptista & Oliveira, 2019)	The extent that an employee commits to an activity with direction, intensity and perseverance	5-point Likert-type item measuring the extent of agreement

Low levels of employee motivation can be a barrier to adopting and implementing gamification as employees will be less likely to persist with utilising a gamified system (AlManei et al., 2018), particularly in the initial phase when there are likely to be more issues. Well educated employees will be required to maintain and test the gamified system to ensure it meets the strategic objective (García et al., 2017). Employees with higher levels of formal education are more likely to be digitally literate, which will be important in the roll-out of the digital interface on which gamification relies on (García et al., 2017). Table 3-10 shows the additional organisational infrastructure mechanisms required.

Table 3-10: Additional organisational infrastructure mechanisms for the adoption and implementation of gamification lean inventory management

Mechanism: Organisational infrastructure		**Basis**	**Description**	**Measurement**
M-14	Industry 4.0 technologies	(Mayr et al., 2018) (Nacke & Deterding, 2017) (Vukadinovic et al., 2018)	The Industry 4.0 technologies required to enable the gamification of lean inventory management	5-point Likert-type item measuring the extent of agreement
M-15	Performance management system	(Reddy et al., 2019) (Balfaqih et al., 2016) (El-Telbany & Elragal, 2017) (Deterding, 2018)	The extent to which the existing performance management system enables the gamification of inventory management	5-point Likert-type item measuring the extent of agreement

Industry 4.0 technologies namely, human computer interaction, digital simulation/ twin, real-time computing, big-data and data analytics and virtual representation (Mayr et al., 2018) are required to fully enable gamification. Gamification enhances performance management systems (El-Telbany & Elragal, 2017) which implies that an existing performance management system is a key enabler.

3.3.4 ***Hypotheses***

The integration of gamification and lean inventory management as conceptualized in Figure 3-3 results in the generation of additional hypotheses which can be tested:

Null Hypothesis H0-3: Firms which have adopted and implemented gamified lean inventory management have no difference in inventory days compared to firms which have not adopted gamified lean inventory management

Alternate Hypothesis H-3: Firms which have adopted and implemented gamified lean inventory management have a difference in inventory days compared to firms which have not adopted gamified lean inventory management

Null Hypothesis H0-4: The absence of digital technology is not a barrier to the adoption and implementation of gamified lean inventory management

Alternate Hypothesis H-4: The absence of digital technology is a barrier to the adoption of gamified lean inventory management

Null Hypothesis H0-5: There is no relationship between lean inventory management and gamification mechanics

Alternate Hypothesis H-5: There exists a relationship between lean inventory management and gamification mechanics

3.4 Conclusion

The conceptual models developed in this section draw from the preceding literature review to define key variables which have been used to derive hypotheses. The variables have been described, linked to literature and measurements have been proposed. The conceptual model has provided a link between the research objectives and supporting literature and forms an input to the research methodology. The subsequent section will unpack the research approach, design and method to ensure consistency. The hypotheses are restated below for ease of reference:

Null Hypothesis H0-1: Firms which have adopted and implemented lean inventory management have no difference in inventory days in comparison to firms which have not adopted lean inventory management

Alternate Hypothesis H-1: Firms which have adopted and implemented lean inventory management have a difference in inventory days in comparison to firms which have not adopted lean inventory management

Null Hypothesis H0-2: Organisational management is not a barrier to the adoption and implementation of lean inventory management

Alternate Hypothesis H-2: Organisational management is a barrier to the adoption and implementation of lean inventory management

Null Hypothesis H0-3: Firms which have adopted and implemented gamified lean inventory management have no difference in inventory days compared to firms which have not adopted gamified lean inventory management

Alternate Hypothesis H-3: Firms which have adopted and implemented gamified lean inventory management have a difference in inventory days compared to firms which have not adopted gamified lean inventory management

Null Hypothesis H0-4: The absence of digital technology is not a barrier to the adoption and implementation of gamified lean inventory management

Alternate Hypothesis H-4: The absence of digital technology is a barrier to the adoption of gamified lean inventory management

Null Hypothesis H0-5: There is no relationship between lean inventory management and gamification mechanics

Alternate Hypothesis H-5: There exists a relationship between lean inventory management and gamification mechanics

CHAPTER 4. RESEARCH METHODOLOGY

4.1 Introduction

Chapter 3 introduced detailed conceptual models which provided a model for testing the hypotheses to satisfy the research objectives. The overall research approach, design, data gathering and analysis techniques used to examine the conceptual model and achieve the research objectives will be presented in this Chapter. The research methodology was applied to demystify whether the inventory performance of a firm can be improved through the combination of lean management, inventory management and gamification practices.

4.2 Research approach

According to Antwi and Hamza (2015), there are three significant differences between quantitative and qualitative approaches. The emphasis on understanding over explaining a phenomenon is the focus of quantitative research. The role of the researcher in quantitative research is impersonal and the intent is to construct knowledge for causal explanation (Antwi & Hamza, 2015). Figure 4-1 assesses the strengths and weaknesses of the approaches

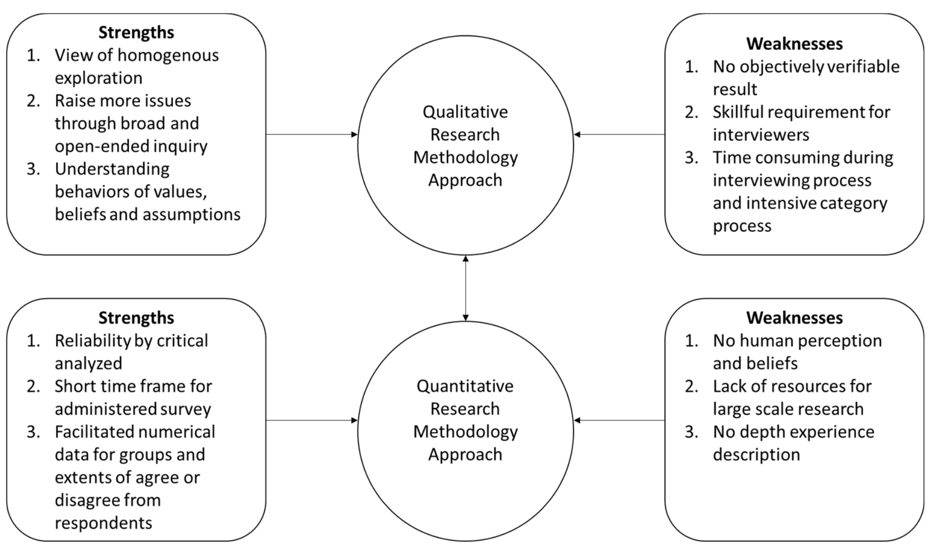

Figure 4-1: A model of strengths and weaknesses of quantitative and qualitative research approaches (Choy, 2014, p. 101)

As shown in Figure 4-1, the strengths of quantitative research are reliability, quick turnaround and numerical data which can be analysed to reveal patterns in data. The main weaknesses are a lack of depth in describing experiences and taking perceptions into account. The quantitative research approach was appropriate for this research as it enables the study to be completed within an acceptable time frame and is appropriate fit for the research objectives of determining prevalence, elucidating relationships and quantifying barriers across an industry.

The research approach describes the relevance, teleology, and research category, linkage to theory, data acquisition and data analysis strategy. Figure 4-2 summarises the research approach.

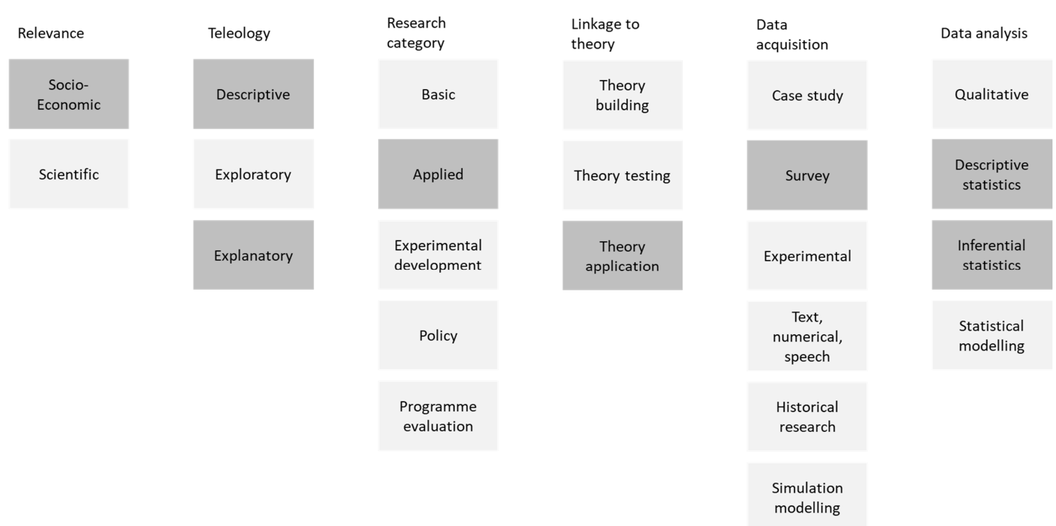

Figure 4-2: Overall research approach adapted from Mashinini (2016, p. 38)

Figure 4-2 summarises the options selected in the overall research approach. The options relevant to this research are shaded in dark grey for clarity. The relevance of the research was socio-economic as the research findings are primarily intended to assist actors in the inventory management process to improve inventory leanness by adopting gamification. The teleology was largely descriptive and explanatory in that the research aims to describe the prevalence of gamified inventory management system and explain the potential barriers to adoption and implementation. The research was an application of existing constructs and theories and was linked to theory through the application of theory. Data acquisition was by survey and data analysis by descriptive and inferential statistics, in line with the general quantitative positivistic approach.

4.3 Research design

Edmondson and McManus (2007), recommend selection of research methodologies based on assessing the prior theory and research maturity relating to the study. Lean management, gamification and inventory management are well researched knowledge areas with established constructs, supported by the s-curve analyses shown in Figures 2-4 and 2-5. According to Edmondson and McManus (2007), this qualified the prior research and theory classification as in the mature stage. The research design included collecting quantitative data typically using surveys, hypothesis testing, statistical analyses and reliance on existing constructs and measures. Following this approach avoided generating obvious findings that lack novelty (Edmondson & McManus, 2007) while ensuring consistency with the positivistic research approach.

4.4 Data collection methods

Survey questionnaires are typically used to profile a population where respondents may be selected to answer in their individual capacities, or to represent their team, organisation or industry (Rowley, 2014). Questionnaires are normally used when it is required to collect data from many respondents. The advantage of using questionnaires is that responses can be collected from a large number of respondents, improving the probability of generalizability (Rowley, 2014). For this study, data collection involved distributing self-administered questionnaires online for completion. The benefits of this collection method are low administration cost, quick turnaround time, and anonymity. The fact that the survey is self-administered resulted in disadvantages such as a weak ability to manage responses and response rates (Rowley, 2014).

Data was collected by means of an online survey questionnaire which was completed by the target respondents. According to Sweeney et al. (2015), survey questionnaires are suitable when the aim of the research is to describe the prevalence of a phenomenon, consistent with the research methodology. Appendix B contains the survey questionnaire.

Lietz (2010), provides some considerations for questionnaire design:

1. Questions should be concise, clear, specific and relevant to the research objective
2. Likert-type response scales ideally should range between 5 to 8 response options
3. More specific questions should be preceded by more general questions

The online survey questionnaire was developed using SurveyMonkey © and is attached in Appendix B. The questionnaire was developed using the descriptions in Tables 3-1 to 3-10

4.5 Population and sample

The population and sample of the research is an important consideration to ensure that the research objectives are answered. Figure 4-3 outlines the unit of analysis, population, sample frame and sample.

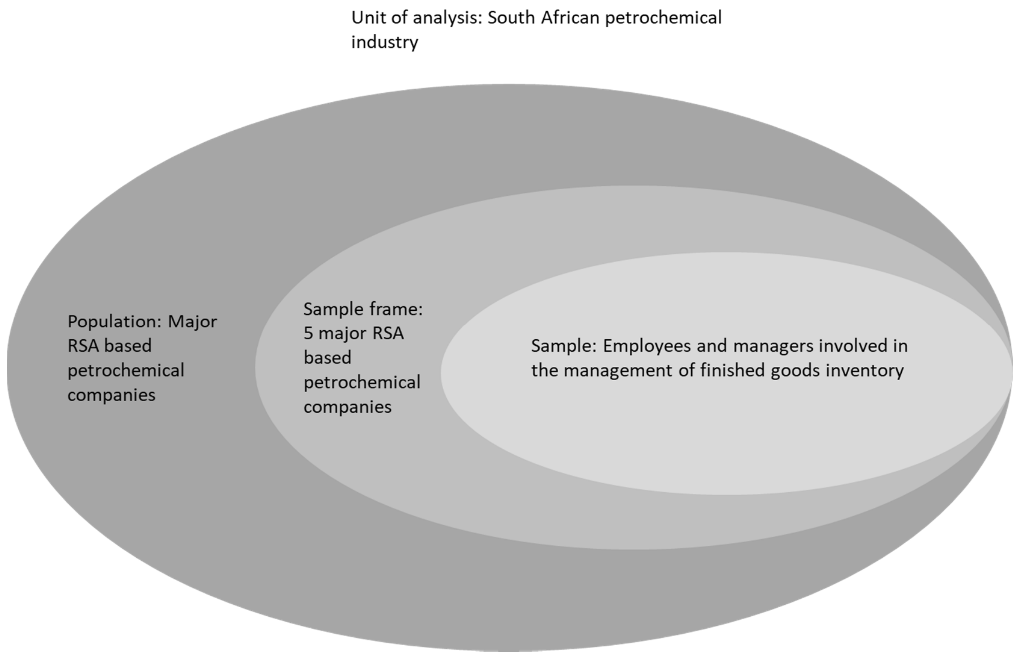

Figure 4-3: Population, sample and sample frame

As presented in Figure 4-3, the sample is a subset of the population, which is selected to analyse SA based large petrochemical firms. Employees and managers of petrochemical companies will be surveyed as representatives of the companies.

4.5.1 ***Population***

The analysis unit was the SA petrochemical process industry and the population is SA located petrochemical firms. Small, medium and micro enterprises were excluded from the population as these organisations were unlikely to have the resources required for full lean implementation according to Slack et al. (2013) and Demeter and Matyusz (2011).

The total number of employees in green occupations was approximately 14500 (CHIETA, 2014). Employees which will likely be most involved in the management of inventory include supply chain professionals, production and sales planners and operations managers. These employees typically are from industrial and chemical engineering occupations, which is a total of approximately

1482 employees (CHIETA, 2014). The population of employees specifically involved in inventory management was estimated at 20% which is 296.

4.5.2 ***Sample and sampling method***

The sample frame was five major SA located petrochemical companies and the sample was of the employees and managers of these companies. Employees and managers of petrochemical companies were taken as representatives of the companies. Table 4-1 summarises the profile of the respondents.

Table 4-1: Profile of respondents

Description of respondent	**Number to be sampled**
Supply chain professional	24
Production planner	24
Sales/ demand planner	24
Operations manager	24

The respondents (shown in Table 4-1) were purposively targeted for the research as these actors were most likely to understand inventory management based on their involvement in the supply chain. Specifically, a stratified sample of employees in the supply chain, production and sales (also known as demand) planning and operations management were the target respondents as these actors are knowledgeable of the inventory management practices in their companies. An equal sample size of the different respondents was targeted to provide a balanced view. The number of years' experience was collected with a targeted even distribution to improve the generalisability of findings, according to Hamari and Koivisto (2015).

The data which will be collected by survey using Likert-type items is ordinal but will be treated as continuous variables when combined to form a scale (Harpe, 2015). According to Bartlett, Kotrlik, and Higgins (2001), for continuous data with a population size of 296, a margin of error of 3%, and equal tails in the distribution of 2.5% each is approximately 85 respondents. Potential participants were also requested to send the survey on to colleagues within their organisation who they believed would find the questionnaire useful to maximise response diversity.

Minimising the likelihood of committing type I and type II errors requires a minimum sample size of 85. The study was cross-sectional requiring captured data to be from the same period for all the participating firms.

4.6 The research instruments

The research survey had 8 sections:

1. Title page
2. Permission and instructions
3. Definition of key terms
4. Lean inventory management
5. Gamification of lean inventory management
6. Identification of barriers
7. General information
8. Closure

According to Lietz (2010), details in the design of questions and response options can have a significant impact on responses and ultimately the conclusions drawn from the research. Lietz (2010), recommends that questions are not longer than 20 words in length to increase respondents' understanding of the question. Grammar was kept simple and negatively worded statements were avoided to reduce the likelihood of respondents making mistakes or becoming confused (Lietz, 2010). Demographic questions were asked at the end of the survey to avoid potential negativity surrounding sharing personal information impacting on the participation or answers (Lietz, 2010).

The questionnaire was comprised of thirty-three questions divided into four sections. Section one had six Likert-type questions which were intended to determine whether the firm manages inventory with a lean approach and thus the extent of leanness. Section two was comprised of two questions which were intended to determine the respondent's awareness of gamification as well as the presence of gamification mechanics in their firm. Section three focused on the identification of barriers by asking nineteen Likert-type questions each representing the quantifiable inputs, controls and mechanisms identified in Tables 3-1 to 3-10. Section four comprised of six questions which characterised the respondent as well as the socio-technical system within which they operate. The inventory performance measure was designed as a continuous scale to allow respondents to provide as accurate data as possible.

4.7 Procedure for data collection

A data collection methodology similar to that used by Soliman et al. (2018), was used. An e-mail link to the survey was sent to potential respondents via e-mail. The e-mail addresses of respondents was obtained during the process of requesting permission from respondent firms. The allowed the respondent to answer the survey from a mobile device or computer for more convenience and ease. The procedure for distributing the questionnaire was as follows:

1. Formal permission was obtained from the petrochemical companies identified to form part of the study by contacting company employees through LinkedIn and other social media channels. The completed permission letters are available but have been omitted from this report to maintain anonymity
2. The person responsible for assisting to obtain permission from the specific company was requested to forward the e-mail with survey completion instructions to relevant participants forming part of the sample
3. The respondents were given 1 month to complete the survey
4. Weekly reminders were e-mailed to respondents to encourage them to complete the survey

Pre-testing the questionnaire with a few members of the target population prior to wide distribution was required to ensure that the questions and flow are clear (Lietz, 2010) and reliability can be tested using Cronbach's alpha (Welman, Kruger, & Mitchel, 2005) and intraclass coefficients (Koo & Li, 2016). The procedure for pre-testing the questionnaire was as follows:

1. Four additional questions were added to the questionnaire to obtain feedback from respondents on ease, comfort, clarity of the questionnaire and one open-ended question for general comments
2. Potential respondents were all selected based on forming part of the targeted profile
3. A link to the survey was e-mailed to 13 potential respondents based on convenience sampling (10% of total target sample)
4. Respondents were informed beforehand that they were taking a pilot survey
5. Respondents were given 8 days to complete the survey
6. The results were analysed to determine areas of improvement, including applying Cronbach's alpha for internal consistency

The results of the pre-test survey are shown in Appendix C. The final questionnaire was administered using SurveyMonkey © as it was discovered that certain firms block access to Google forms © during the pre-test, lowering the survey completion rate. Using SurveyMonkey © decreased the likelihood of not obtaining responses due to the site being blocked by organisations.

4.8 Data analysis and interpretation

The study was quantitative in nature and formal hypothesis testing using inferential statistics was conducted. IBM SPSS 25 was used to test for normalcy of the data collected. If the data distribution was normal, formal hypothesis testing was conducted using parametric statistics such as Pearson's correlation and analysis of variance. If the data distribution deviated significantly from normalcy, non-parametric statistical tests such as Spearman's rho and Kruskal-

Wallis was used (Harpe, 2015). K-means clustering is an exploratory method which has been used for identifying underlying data relationships by clustering data into mutually exclusive groups (Jain, 2010). This method was used by Soliman et al. (2018) to group companies according to adoption levels of lean. Demeter and Matyusz (2011), also use the k-means clustering method to categorise companies between lean and non-lean. K-means clustering method was used in this research to classify companies between lean and non-lean as well as gamified and ungamified.

Statistical significance was based on resultant p-values less than 0.05, which is commonly applied in the social sciences (Benjamin et al., 2018). The categorisation of research variables was as follows:

1. The dependant variable was inventory performance
2. The independent variables were the extents of lean inventory management and gamification
3. Potential contingency variables included organisational culture and the diversity of the workforce in the different firms

A data table summarising the descriptive statistics per question will provided in Chapter 5.

4.9 Limitations of the study

1. Respondents have an accurate understanding of the inventory performance and annual revenue of their companies
2. Respondents will be truthful about the inventory performance of their firms negating the need for archival research
3. The study is cross-sectional, thus the longitudinal impacts of gamification cannot be assessed

4.10 Validity and reliability

4.10.1 ***External validity***

The study will be generalizable as the respondents were randomly selected from the 5 major petrochemical companies operating in South Africa in order to ensure that the sample is representative (Welman et al., 2005). Ecological validity can be determined by repeating the study with petrochemical companies in Nigeria or other developing countries with a low country skills base. Temporal validity can be established by repeating the study after 2 years to obtain longitudinal data. Ecological and temporal validity are delimitations of this study.

4.10.2 ***Internal validity***

According to Welman et al. (2005), internal validity can be created by randomising participants and minimising factors beyond control. The threats of history and spontaneous change were minimized by completing the study over a short period of time. The threat of other variables has been managed by developing a detailed conceptual model which identifies relevant variables to the research and have been taken into consideration during research planning. The factors considered in this study that make the research novel, such as the low skills base in South Africa, is equally applicable to all participants in the research as they are all based in South Africa. Statistical conclusion validity was established by setting the alpha confidence level at 95%. Content validity was established by grounding the design of the survey by an extensive literature review.

4.10.3 ***Reliability***

Piloting/ pre-testing the survey with a few members of the target population prior to wide distribution will be required to ensure that the questions and flow are clear (Lietz, 2010) and internal consistency can be tested using Cronbach's alpha. The procedure for pre-testing the survey is detailed in Section 4.7 above. Internal structure validity was confirmed by executing confirmatory factor analyses. Testretesting was done to determine the intraclass coefficient (ICC) reliability index (Koo & Li, 2016) for the gamification mechanics scale.

4.11 Ethical considerations

Ethics needed to be considered in the research to ensure that no harm was done to the respondents or the researcher as a result of conducting this research. Table 4-2 shows ethical principles considered in this research.

Table 4-2: Ethical principles considered in this research adapted from (Bell & Bryman, 2007)

Ethical principle	Consideration
Harm to participants	The respondents or researcher were not coerced physically or psychologically into administering or completing the survey
Informed consent	Request for consent from the respondents was requested in the e-mail invitation as well as before the questions in the survey questionnaire
Anonymity	No data which enables the identification of an individual or a company was collected or reported
Dignity	There were no questions asked which were not relevant to answering the research objectives or which caused discomfort or anxiety to respondents
Privacy	The survey was administered online and there was no contact between the administrator and the respondent. The respondent could decline participation in the research upfront if they believed it invaded their privacy
Confidentiality	The data gathered was only used for research purposes. Information gathered does not allow a third party to identify the respondent or organisation

Ethical principle	Consideration
Affiliation	The research project was affiliated with Wits Business School and all information gathered under this auspice may only be used for academic purposes
Honesty, transparency and reciprocity	The respondent was given the opportunity to request feedback on the survey results if they so wish, ensuring transparency of the use of the data

The eight ethical considerations improved the proactive management of potential ethical issues. Furthermore, there were no potential conflicts of interest with respect to this research. Ethical approval from the University of the Witwatersrand was sought and approved. The ethical clearance certificate is attached in Appendix E.

4.12 Conclusion

The research methodology which was applied towards testing the hypotheses formulated in Chapter 3 has been described. A consistency matrix summarising the alignment between the research methodology and research objectives is presented in Appendix A. The results gathered from the execution of the research approach will be presented and discussed in Chapter 5. Key findings will be concluded in Chapter 6 including recommendations for practitioners and academics.

CHAPTER 5. SURVEY RESULTS, DISCUSSION & SYNTHESIS

5.1 Introduction

The results of all the data gathered from the survey questionnaire distributed to 5 major SA based petrochemical companies will be presented in this Chapter. The results of formal hypothesis testing are presented in accordance with the 5 hypotheses. The construction of scales and classification of variables will also be presented and discussed to ensure correct statistical procedures are applied.

5.2 Demographic profile of respondents

The demographic profile of the respondents is important to determine the stratification of the sample based on the sampling criteria described in Chapter 4. The more stratified the sample, the lower the likelihood of sample bias, improving the generalisability of the results. Figure 5-1 presents the respondents' functional areas.

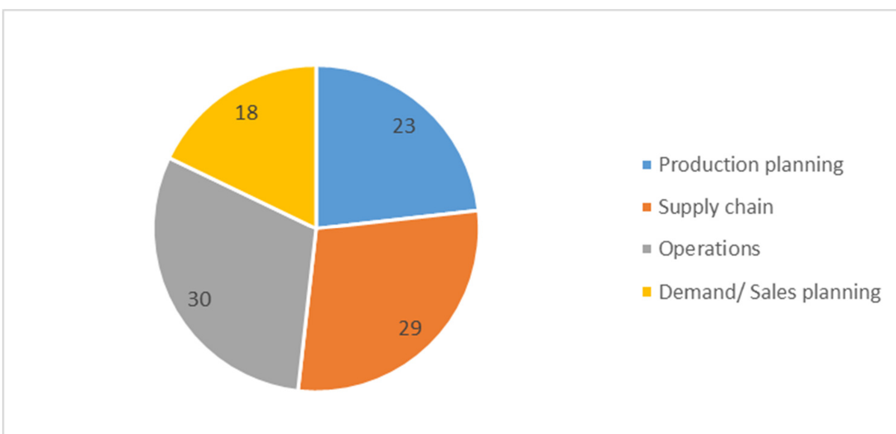

Figure 5-1: Respondent functional areas

As shown in Figure 5-1 above, the range of the respondents per functional area is 12. Production planning had the least number of respondents while operations had the most. Demand/ sales planning is underrepresented relative to the other categories. Compared to the targeted respondent distribution, the results are heterogeneous and in line with the research design. Figure 5-2 shows the number of years of experience of the respondents.

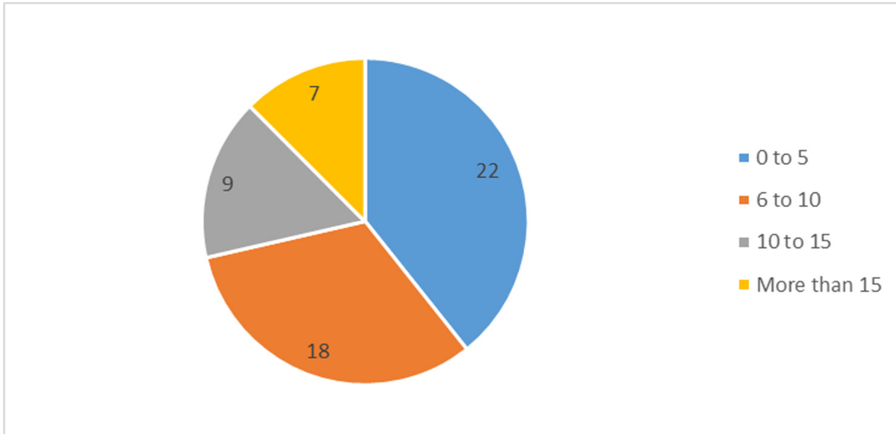

Figure 5-2: Respondent years of experience

As shown in Figure 5-2 above, most respondents have between 0 to 5 years of experience. As the years of experience increases, the number of qualifying respondents decreases. The resultant sample stratification reduces the likelihood of sample bias, improving generalizability to the population of inventory actors (Hamari & Koivisto, 2015).

5.3 Overview of data gathered

The data gathered by survey questionnaire is presented in this section. The data gathered will be separated into sections, based on the variable measurement classification of discrete or continuous data (Welman et al., 2005). For discrete data, such as ordinal Likert-type items, appropriate descriptive statistics include frequency, mode and median. For continuous data, such as Likert-scale items, appropriate descriptive statistics include standard deviation and mean (Boone & Boone, 2012).

5.3.1 *Data coding methodology*

The data collected by means of survey questionnaire is coded to enable quantitative statistical procedures to be applied. The data was coded using

Microsoft Excel 2013 © to apply conditional IF statements based on the results of the data obtained. Tables 5-1 to 5-3 detail how the collected data has been coded:

Table 5-1: Coding of ordinal variables (Questions 1 - 6 and 9 - 27)

Response option	Code assigned
Strongly disagree (SD)	1
Disagree (D)	2
Neither agree nor disagree (N)	3
Agree (A)	4
Strongly agree (SA)	5

As shown in Table 5-1 above, the response options have been assigned codes in increasing increments of 1. The assignment of codes does not assume that the distance between each response option is equidistant, which is in line with the classification of ordinal variables. No reverse scoring was applied, allowing scales to be constructed by using the conceptual model detailed in Chapter 3 to summate related question scores. Table 5-2 shows the coding applied to dichotomous variables

Table 5-2: Coding of dichotomous variables (Questions 7, 8, 28 and 32)

Response option	Code assigned
Yes	1
No	0

Table 5-2 above shows the code assignment for dichotomous variables. The dichotomous variables are classified as ordinal as they reflect the extent of agreement to the question posed. Specific to gamification mechanics (Question 8), additional consideration was given to allowing more response options to create a 5-point Likert-item. Less response options create less ambiguity for the respondent to maximise completion rates. The pre-test survey (Appendix C) also showed that most respondents were unfamiliar with the concepts and mechanisms of gamification. Thus, dichotomising the answer choices will maximise the likelihood that the respondent takes a firm position and provides more credible data. Table 5-3 shows the coding applied to nominal variables.

Table 5-3: Coding of nominal variables (Question 29)

Response option	Code assigned
Production planning	1
Supply chain	2
Operations	3
Demand/ Sales planning	4

As shown in Table 5-3 above, the nominal variables have been assigned codes to separate different groups of respondents according to their work function within their company. The code is arbitrarily assigned and does not indicate any order. The coding and classification of the variables is critical to ensure that the correct statistical tests are applied to answering the research objectives (Rowley, 2014). The construction of scales from the ordinal data collected will be discussed further in the next section.

5.3.2 *Construction and validation of scales*

The detailed conceptual framework discussed in Chapter 3 and the literature review presented in Chapter 2 provide the foundation for determining which Questions are to be summated to construct a scale. Chapter 4 details the measures taken to maximise the validity of the study. Factor analysis, Cronbach's Alpha, and Intraclass correlation coefficients (ICC) calculated on test-retest data collected have been executed to construct internally consistent scales at an appropriate statistical significance (Sig) level of less than 0.05. Table 5-4 shows the summary of the constructed scales.

Table 5-4: Summary of constructed scales

Scale	Ques.	Formula	Cronbach alpha	ICC	Sig
Lean Inventory Management practices	2 to 6	Sum	0.823		
Gamification	8.1 to 8.10	Sum		0.921	0.001
Control barriers	9 to 13	Mean	0.798		
Organisational management barriers	14 to 19	Mean	0.827		
Organisational employees' barriers	20 to 23	Mean	0.719		

Scale	Ques.	Formula	Cronbach alpha	ICC	Sig
Organisational infrastructure barriers	24 to 27	Mean	0.784		

Table 5-4 above shows that all of the scales constructed have acceptable internal consistency as measured by Cronbach's alpha greater than 0.7 (Gliem & Gliem, 2003) at a 95% confidence interval. Question 1 was omitted in the construction of the lean inventory management practices scale as it improved the reliability from 0.697 to 0.823. The barrier scales are calculated as means and not summated else the scale with the greatest number of questions will be incorrectly identified as the largest barrier (refer to Appendix D for details).

The gamification scale is summated from dichotomous items. The logical justification is that the more gamification mechanics present, the higher the extent of gamification. This approach is in agreement with the approach used by Beck et al. (2019), in determining the gamification utilisation level. The maximum possible summated item score is 9, which is the score if all gamification mechanics are present. The minimum score is 0, which reflects that no gamification mechanics are present. In order to establish the reliability of the construct statistically, the intraclass correlation coefficient (ICC) is applied. After administering the survey, respondents who indicated that they would like to receive survey feedback, were requested to take part in a re-test survey only focused on the gamification mechanics. In total, 22 surveys were distributed, and 9 responses were received for a response rate of 41%. The survey was distributed between 2 and 4 weeks after respondents had taken the full survey to reduce the probability of time-distorted results.

According to Koo and Li (2016), a two-way mixed effects model with a single measurement and absolute agreement is appropriate for a test-retest reliability study. An ICC of 0.921 with a 95% confidence interval is obtained at a significant level of 0.001 indicating excellent reliability (Koo & Li, 2016). Appendix D provides the detail results for the statistical procedures used to validate the construction of the scales.

5.3.3 ***Summary of data gathered***

The data gathered as well as the scales developed will be presented in this section. The survey was distributed to approximately 450 respondents and 62 responses were received, translating to a 13.8% response rate. The survey was completed by 56 respondents, resulting in a 90% survey completion rate. The total number of responses received represents 65% of the calculated sample size required to minimise Type II error.

Harpe (2015) agrees with Boone and Boone (2012) on the appropriate descriptive and inferential statistical procedures for discrete and continuous data. Appropriate measures of central tendency and variability for discrete data is median and frequency respectively. Appropriate measures of central tendency and variability for continuous data are means and standard deviations respectively. Table 5-5 shows the discrete data gathered, relating to Questions 1 to 29 and Question 32. Table 5-5 also includes the results of dichotomous variables (Questions 7, 8, 28 and 32). Table 5-6 shows the continuous data gathered, relating to Questions 30, 31 and 33. Table 5-7 shows the results of the scales constructed in Section 5.2.2 above.

Table 5-5: Results and descriptive statistics of discrete data gathered including dichotomous variables

Question number	Question description	SD= 1/ Yes=1	D= 2	N= 3	A= 4	SA= 5	No= 0	Total	median	mode
1	Your organisation views inventory as waste which needs to be minimized	9	16	8	22	7	0	62	3	4
2	Customer value focus drives decision making in the inventory management process	3	9	6	27	17	0	62	4	4
3	Employees are empowered to take decisions to improve inventory performance	4	13	6	25	14	0	62	4	4
4	The organisational culture supports the continuous improvement of inventory performance	4	9	11	26	12	0	62	4	4
5	The organisation aims to reduce the complexity of the inventory management process	4	17	14	24	3	0	62	3	4
6	The goal is the pursuit of perfection of inventory performance	4	10	14	28	6	0	62	4	4
7	Are you familiar with the concept of gamification, where game-design elements are used in non-game contexts to improve employee engagement?	21	0	0	0	0	40	61	0	0
8	Gamified processes have at least one of the below mechanics. Please select the mechanics present in your inventory management process									
8,1	Leader boards, badges and points	7	0	0	0	0	55	62	0	0
8,2	Increasing task difficulty	7	0	0	0	0	55	62	0	0
8,3	Finite end	1	0	0	0	0	61	62	0	0
8,4	Multiplayer orientation	11	0	0	0	0	51	62	0	0
8,5	Infinite play	1	0	0	0	0	61	62	0	0
8,6	New levels	2	0	0	0	0	60	62	0	0
8,7	Team playing	13	0	0	0	0	49	62	0	0

Question number	Question description	SD= 1/ Yes=1	D= 2	N= 3	A= 4	SA= 5	No= 0	Total	median	mode
8,8	Online playing	4	0	0	0	0	58	62	0	0
8,9	Real world playing	1	0	0	0	0	61	62	0	0
8,10	None of the above	31	0	0	0	0	31	62	0,5	1
9	Organisational strategy is a barrier to gamified lean inventory management in my organisation	3	15	17	20	5	0	60	3	4
10	Industry standards are a barrier to gamified lean inventory management in my organisation	2	21	15	21	1	0	60	3	2
11	Applicable regulations are a barrier to gamified lean inventory management in my organisation	3	18	15	23	1	0	60	3	4
12	Lean inventory management practices are a barrier to gamified lean inventory management in my organisation	0	22	22	16	0	0	60	3	3
13	Gamification practices are a barrier to gamified lean inventory management in my organisation	0	19	28	12	1	0	60	3	3
14	Human resource management is a barrier to gamified lean inventory management in my organisation	1	23	16	15	3	0	58	3	2
15	Management focus is a barrier to gamified lean inventory management in my organisation	1	14	17	21	5	0	58	3	4
16	Change management is a barrier to gamified lean inventory management in my organisation	2	13	17	22	4	0	58	3	4
17	Human-machine interface management is a barrier to gamified lean inventory management in my organisation	3	14	17	21	3	0	58	3	4
18	Digital transformation management is a barrier to gamified lean inventory management in my organisation	4	17	11	23	3	0	58	3	4
19	Lean inventory management is a barrier to gamified lean inventory management in my organisation	2	24	22	10	0	0	58	3	2

Question number	Question description	SD= 1/ Yes=1	D= 2	N= 3	A= 4	SA= 5	No= 0	Total	median	mode
20	Employee resistance is a barrier to gamified lean inventory management in my organisation	2	19	5	23	9	0	58	4	4
21	Employee training is a barrier to gamified lean inventory management in my organisation	1	18	9	25	5	0	58	4	4
22	Employee education level is a barrier to gamified lean inventory management in my organisation	3	22	12	19	2	0	58	3	2
23	Employee motivation is a barrier to gamified lean inventory management in my organisation	3	15	9	27	4	0	58	4	4
24	Software and computer infrastructure are a barrier to gamified lean inventory management in my organisation	3	23	11	16	5	0	58	3	2
25	Hardware and facilities are a barrier to gamified lean inventory management in my organisation	2	17	13	23	3	0	58	3	4
26	Industry 4.0 technologies is a barrier to gamified lean inventory management in my organisation	4	19	18	14	3	0	58	3	2
27	The performance management system is a barrier to gamified lean inventory management in my organisation	2	14	13	24	5	0	58	3,5	4
28	Are you involved in the inventory management process of your organisation?	46	0	0	0	0	10	56	1	1
29	Which function do you work for in your organization?	13	16	17	10	0	0	56	2	3
32	Is improving inventory performance to optimise working capital a strategic objective in your organisation?	49	0	0	0	0	10	59	1	1

Table 5-5 shows a summary of the discrete data gathered. The responses range from a minimum of 56 to a maximum of 62, indicative of the 90% response rate. The number of responses decreases slightly as the survey progresses. Three distinct drop off points can be identified; after the identification of gamification mechanics, after the control barriers and questions that define respondent demographics. Table 5-6 shows the descriptive statistics of the continuous data gathered.

Table 5-6: Descriptive statistics of continuous data gathered

Question number	Question description	Mean	Standard Deviation
30	How many years of inventory management experience do you have?	8,3	6,8
31	What is the inventory performance of your organisation in days of inventory?	37,1	30,7
33	What is the annual revenue of your company in ZAR Millions?	54920,3	114406,6

The means and standard deviations were calculated using Microsoft Excel 2013. The results have been rounded off to 1 decimal point. Table 5-7 shows the descriptive statistics of the scales constructed using the formulae from Table 5-4

Table 5-7: Descriptive statistics of the scales formulated from the data gathered

Scale description	Mean	Standard Deviation
Lean Inventory Management practices	17,57	6,16
Gamification	0,76	0,99
Control barriers	2,99	0,68
Organisational management barriers	3,05	0,72
Organisational employees' barriers	3,18	0,80
Organisational infrastructure barriers	3,06	0,82

Table 5-7 shows the descriptive statistics of the scales constructed from individual questions. For lean inventory management practices, gamification and all the barriers the maximum attainable mean scores are 25, 9 and 5 respectively. The normality of the distributions of the continuous data and scales is tested to ensure the correct statistical procedures are applied for hypothesis testing. Normalcy is evaluated using the following criteria:

1. Skewness between -1 and 1 (Höllig et al., 2018)
2. Kurtosis between -1 and 1 (Höllig et al., 2018)
3. Shapiro-Wilk test of normality p-value < 0.05 (Das & Imon, 2016)

Based on the results of the skewness, kurtosis and Shapiro-Wilk statistic (refer to Appendix D for the detailed SPSS output), the following variables are non-normal:

1. Degree of gamification
2. Inventory performance
3. Annual revenue
4. Employee barriers

Non-parametric statistical tests will need to be applied when evaluating hypothesis relating to the above 4 variables. Tables 5-1 to 5-7 have summarised the data collected as well as outlined the coding of responses and detailed the construction of scales.

5.4 Results pertaining to Hypothesis 1

Hypothesis 1 is formulated to elucidate the relationship between lean inventory management and inventory performance. The null hypothesis states that firms which have adopted and implemented lean inventory management have no difference in inventory performance than firms which have not adopted lean inventory management. This hypothesis is tested by determining whether there is a correlation between the lean inventory management practices scale and inventory performance. Both the dependant variable (inventory performance) and the independent variable (lean inventory management practices scale) are continuous variables.

To explore the relationship between lean inventory management and inventory performance, k-means clustering is applied. Figure 5-3 shows the k-means clustering of lean inventory management and inventory performance.

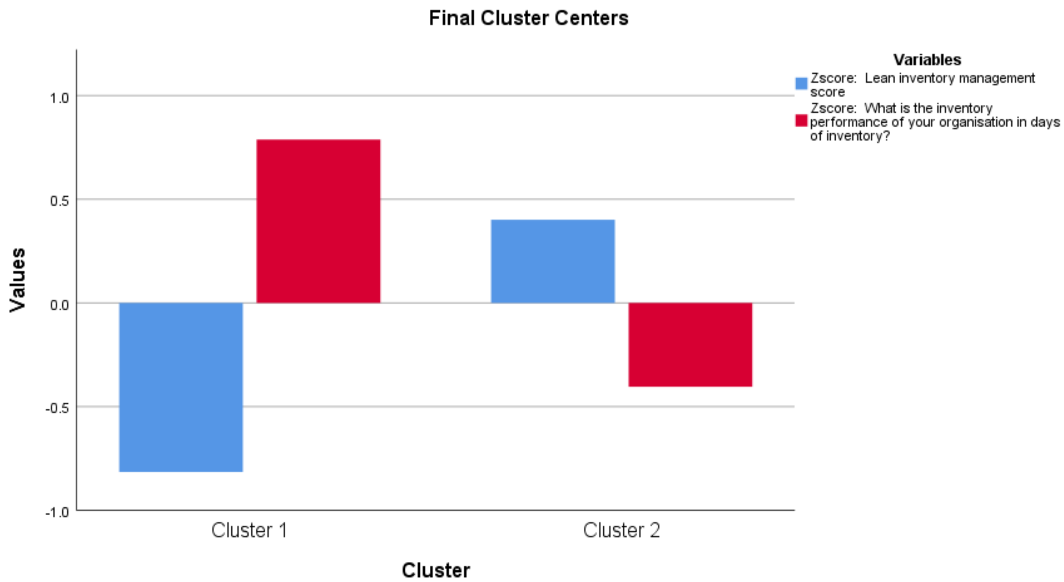

Figure 5-3: K-means clustering of lean inventory management score and inventory performance

Figure 5-3 above shows 2 k-means clusters which are statistically significant at a p-value less than 0.05. The k-means clustering is based on normalised z-scores of inventory performance (Question 31) and the lean inventory management practices scale defined in Table 5-4. The clusters show an inverse relationship between lean inventory management practices and inventory days. The lower the lean inventory management score, the higher the days of inventory, translating to lower inventory performance. This exploratory analysis agrees with the work of Demeter and Matyusz (2011), insofar as firms with a higher degree of implementation of lean inventory management practices will have lower inventory days, with the inverse also holding.

To formally test hypothesis H-1, the differences in distribution of the two clusters will be tested. The underlying data distribution of inventory performance is not normal and thus non-parametric statistical methods are more appropriate (Prion

& Haerling, 2014). IBM SPSS 25 © is used to calculate the Kruskal-Wallis H statistic of 14.091 at a significant p-value less than 0.01. Hypothesis H-1 is thus accepted.

In order to further elucidate the relationship between lean inventory management and inventory performance, correlation was done. Spearman's correlation coefficient test was applied as the inventory performance data is non-normal. Spearman's rho correlation coefficient is 0.147 with a 2-tailed statistical significance value of 0.280. Thus, the correlation between inventory performance and lean inventory management practices isn't a statistically significant.

This lack of correlation is inconsistent with the result obtained by Demeter and Matyusz (2011), who found a significant positive relationship between lean inventory management practices and inventory performance. This may be due to the different industrial context of the study conducted by Demeter and Matyusz (2011). Another possibility is that inventory days does not cater well for the effect of economies of scale (Eroglu & Hofer, 2011). 82% of respondents indicated that they are involved with the inventory management process and so logically it can be inferred they provided accurate estimates of inventory performance. The reliability of the results can be improved by directly obtaining inventory performance data from company archives to eliminate the risk of respondent perception bias of their company performance.

The lack of positive correlation can be due to contingency factors (Bortolotti et al., 2015). Demeter and Matyusz (2011), assert that contingency factors such as employee unionization and the age of a manufacturing plant are not as important as firm size and process type in determining SCM performance. The study excludes small and medium enterprises and focuses only petrochemical companies to minimise the potential impact of contingency factors, which are more likely to be homogenous for firms of similar size and process type. For future correlation analysis, inventory performance could be categorised by firm size and process type in order to more accurately elucidate linkages.

5.5 Results pertaining to Hypothesis 2

Hypothesis 2 is formulated to establish the relationship between organisational management and lean inventory management practices. The null hypothesis states that organisational management has no impact on the adoption and implementation of lean inventory management. This hypothesis will be tested by determining whether there is a correlation between the lean inventory management practices scale and organisational management. Both the dependant variable (lean inventory management practices scale) and the independent variable (organisational management) are continuous variables.

The underlying data distributions of organisational management and lean inventory management practices are both normal and thus parametric statistical methods are more appropriate (Gilbert & Prion, 2016). IBM SPSS 25 © is used to calculate Pearson's correlation coefficient test. Pearson's correlation coefficient is -0.126 with a 2-tailed statistical significance value of 0.346. There is thus no statistically significant relationship between organisational management and lean inventory management practices at a 0.05 statistical significance level. Hypothesis H-2 is thus rejected. Figure 5-4 shows the individual item responses for the organisational management scale to provide more insight. The data has been sorted from highest to lowest according to mode, then mean as the data is ordinal (Harpe, 2015). Standard deviation, from lowest to highest, has been applied as a tiebreaker as lower standard deviation shows items where respondents had the most agreement.

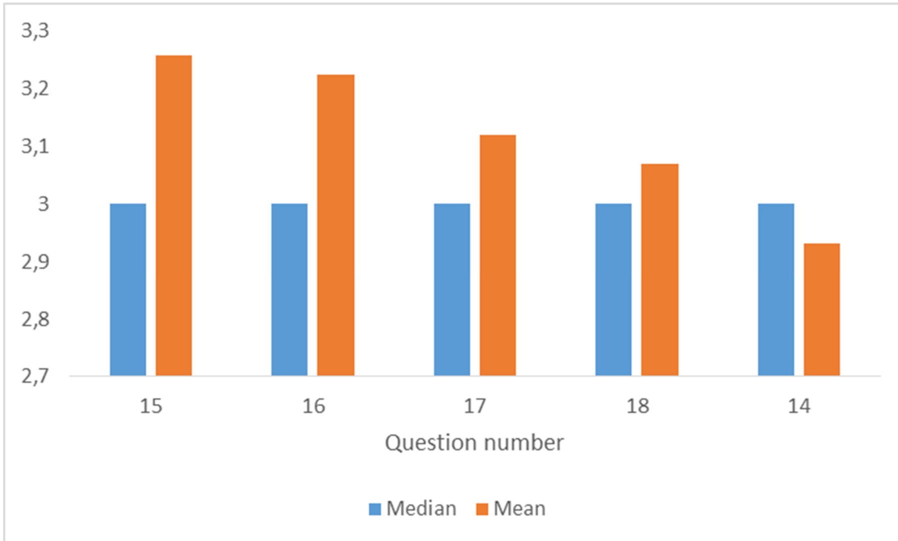

Figure 5-4: Organisational management barriers

As shown in Figure 5-4 above, management focus is the largest organisational management barrier while human resource management is the least. This is conceptually consistent with the work of Alefari et al. (2017), that conclude that focus from organisational management decreases over time, eventually becoming a barrier. This result also suggests that the relationship between lean inventory management and organisational management would be more significant if studied longitudinally.

5.6 Results pertaining to Hypothesis 3

Hypothesis 3 is formulated to establish the relationship between gamified lean inventory management and inventory performance. The null hypothesis states that there is no relationship between gamified lean inventory management and inventory performance (Question 31). This hypothesis will be tested by determining whether there is a correlation between the gamification mechanics scale (refer to Table 5-4) and inventory performance. Both the dependant variable (inventory performance) and the independent variable (gamification mechanics) are continuous variables.

The underlying data distribution of gamification mechanics is not normal and thus non-parametric statistical methods are more appropriate (Gilbert & Prion, 2016). IBM SPSS 25 © is used to calculate Spearman's rho correlation coefficient. Spearman's rho correlation coefficient is 0.095 with a 2-tailed statistical significance value of 0.486. There is thus no statistically significant correlation between gamification and inventory performance at a 0.05 statistical significance level. The absence of a statistically significant correlation may be due to several factors such as:

1. The overall low prevalence of gamification, with 66% of respondents being unfamiliar with the concept of gamification. Furthermore, 50% of respondents indicated that no gamification mechanics were present in their respective inventory management processes
2. Inventory days does not cater well for the effect of economies of scale (Eroglu & Hofer, 2011)
3. The effect of firm size and process type on inventory performance (Demeter & Matyusz, 2011)

Although there isn't a statistically significant correlation between inventory performance and gamified lean inventory management, it is valuable to elucidate the link between lean inventory management and gamification mechanics. Normalised K-means clustering is executed to elucidate the underlying relationship between lean inventory management and gamification mechanics. Figure 5-5 shows the normalised z-score k-means clustering of gamification mechanics and lean inventory management.

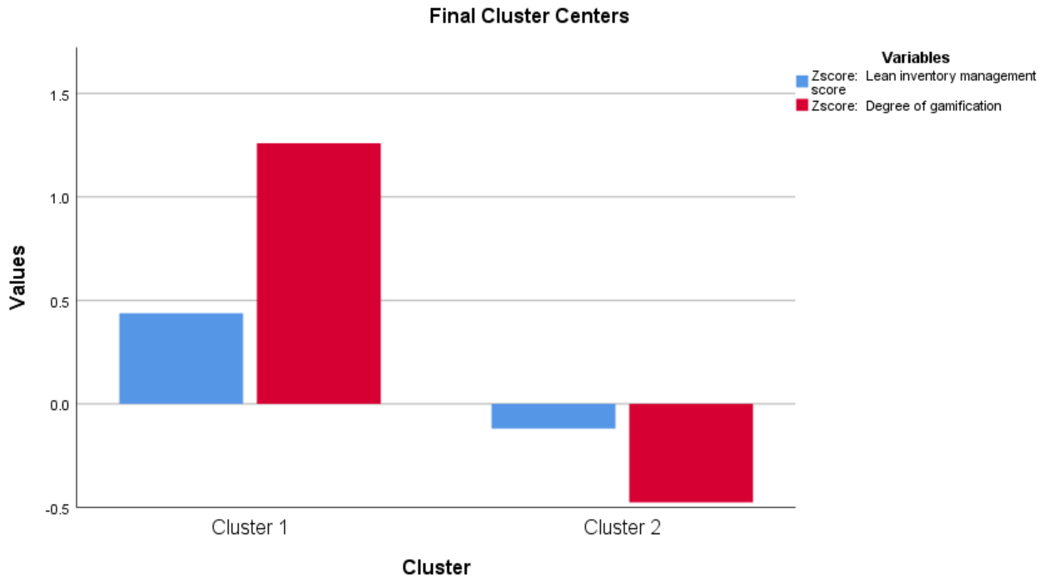

Figure 5-5: K-means clustering of gamification and lean inventory management

As shown in Figure 5-5 above, the normalised Z-scores are classified into 2 statistically significant clusters with resultant p-values less than 0.05. Two groups/ clusters of respondents are classified using k-means:

1. Gamified lean inventory managed firms
2. Ungamified lean inventory managed firms

The resultant clusters show the relationship between lean inventory management and gamification scales defined in Table 5-4. The clustering shows that there is a monotonic relationship between gamification and lean inventory management. In cluster 1, positive z-scores for lean inventory management are related to positive z-scores of gamification while the inverse holds for cluster 2. This exploratory k-means clustering analysis suggests that firms with higher adoption and implementation levels of lean inventory management, have higher a higher degree of gamification.

Based on the results of the exploratory analysis, the chi-square test of differences was conducted to determine whether there is a statistically significant difference in inventory performance between gamified lean inventory management relative to ungamified lean inventory management. The non-parametric chi-square median test has a p-value of 0.007 for a chi-square of 5.878. This shows that there is a statistically significant difference between the inventory performances of gamified lean inventory management relative to ungamified lean inventory management. Hypothesis H-3 is thus accepted.

5.7 Results pertaining to Hypothesis 4

Hypothesis 4 is formulated to identify which is the largest barrier to adopting and implementing the gamification of lean inventory management.

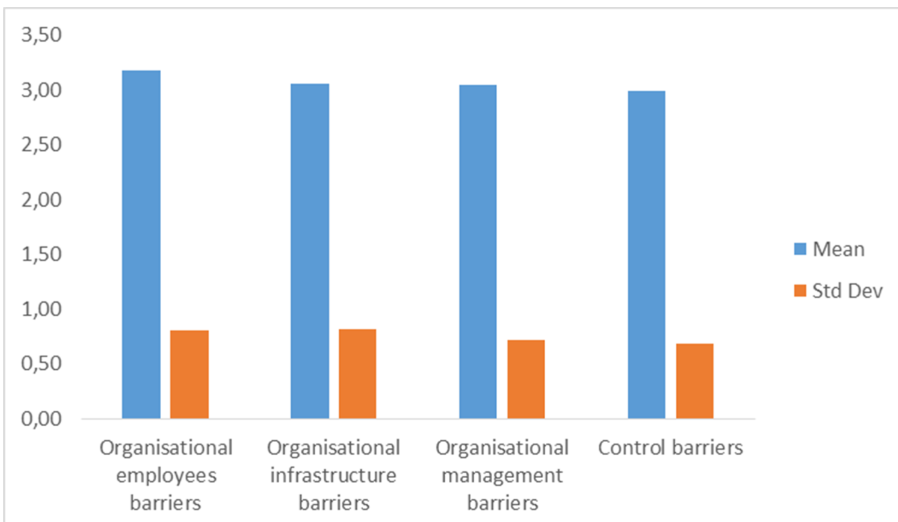

Figure 5-6: Barriers to adoption and implementing gamified lean inventory management

Figure 5-6 shows the descriptive statistics of the quantifiable barriers to the adoption and implementation of gamified lean inventory management. The results have been sorted by mean from highest to lowest, followed by standard deviation from lowest to highest. As shown in Figure 5-6 above, organisational employees are the largest barrier to adopting and implementing gamified lean inventory management. Hypothesis H-4 is thus rejected. 83% of respondents indicated that improving inventory performance to optimise working capital is an organisational strategic objective. Organisational management is a lower barrier when compared to employee factors during the introduction of a lean journey (such as gamifying inventory management) is consistent with the conclusions of Alefari et al. (2017). Figure 5-7 shows the individual item responses for the barriers to adopting and implementing gamified lean inventory management to provide more insight

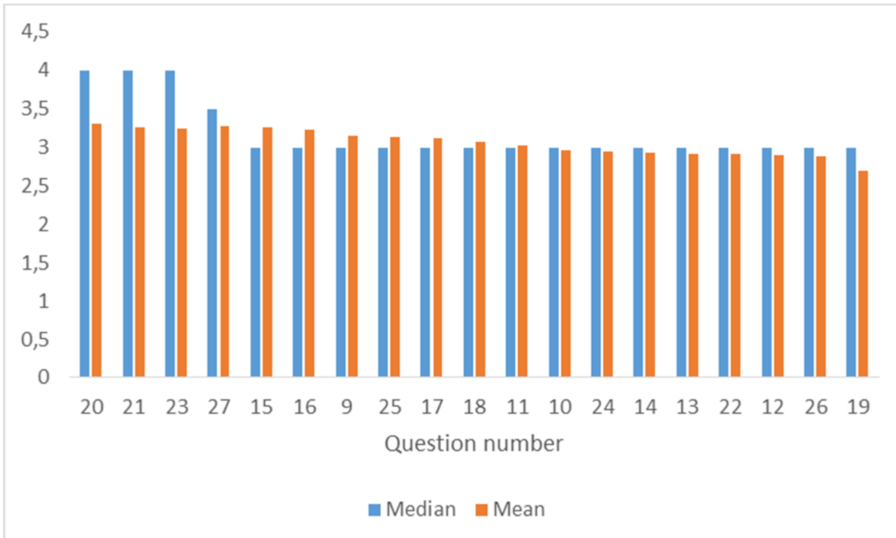

Figure 5-7: Barriers to adopting and implementing of gamified lean inventory management

As shown in Figure 5-7 above, the data has been sorted from highest to lowest according to mode, then mean as the data is ordinal (Harpe, 2015). Standard deviation, from lowest to highest, has been applied as a tiebreaker as lower standard deviation shows items where respondents had the most agreement. The results show that the absence of digital technology is not the most significant barrier to adopting and implementing gamified lean inventory management. The most significant barrier is employee resistance (Question 20), followed by employee training (Question 21) and employee motivation (Question 23). This may be due to the low awareness of gamification, with only 34% of respondents familiar with the concept. This result supports the work of AlManei et al. (2018) in that the complexity of human factors needs to be considered to fully realise the benefits of running a lean organisation.

Employee training is one of the critical success factors for lean and continuous improvement (Alefari et al., 2017). Figure 5-7 shows that the performance management system (Question 27), management focus (Question 15) and change management (Question 16) are the fourth to sixth highest ranking barriers. According to Deterding (2018), digital performance management and behaviour tracking technology is crucial enabler for gamification. This also suggests that addressing management competence can ultimately reduce employee specific barriers. Employee resistance can also be due to a lack of intention, which is a predictor of gamification adoption (Baptista & Oliveira, 2019). Employees may doubt the usefulness or enjoyment gamification which influences intention (Baptista & Oliveira, 2019). Organisations should invest in training programmes to educate employees on the concept and benefits of gamification, to reduce employee resistance as part of a change management process (AlManei et al., 2018). Balancing gamification with usefulness is an iterative process (Baptista & Oliveira, 2019) requiring continuous realignment with users' needs and the digitisation of the performance management system to deal with this volatility (Reddy et al., 2019).

The identification and quantification of barriers contributes to unpacking the requirements of successful gamification, a theoretical agenda point identified by Koivisto and Hamari (2019). As 66% of respondents indicated that they were not familiar with the concept of gamification and 50% of respondents indicated total absence of gamification mechanics, conducting a controlled experiment inclusive of a simulation exercise can provide additional insight to the barriers to adopting and implementing gamified lean inventory management.

5.8 Results pertaining to Hypothesis 5

Hypothesis 5 is formulated to establish the relationship between lean inventory management and gamification mechanics. The null hypothesis states that there is no relationship between lean inventory management and gamification mechanics. This hypothesis will be tested by determining whether there is a correlation between the gamification mechanics scale and lean inventory management scale. Both the dependant variable (inventory performance) and the independent variable (gamification mechanics) are continuous variables.

The underlying data distribution of gamification mechanics is not normal and thus non-parametric statistical methods are more appropriate (Gilbert & Prion, 2016). IBM SPSS 25 © is used to calculate Spearman's rho correlation coefficient test. Spearman's rho correlation coefficient is 0.173 with a 2-tailed statistical significance value of 0.178. Thus, the correlation between gamification mechanics and lean inventory management practices is not established at a 0.05 statistical significance level. Hypothesis H-5 is thus rejected.

Figure 5-5 is further interpreted to elucidate the link between lean inventory management and gamification. By elucidating the link between lean inventory management and gamification, insight may be generated into whether lean is a prerequisite for the adoption of Industry 4.0 technologies (Mayr et al., 2018), such as gamification. The k-means cluster analysis shown in Figure 5-5 above suggests that firms which have a more mature lean inventory management system can adopt more gamification mechanics. This contributes positively to the perspective that lean management is a prerequisite for introducing Industry 4.0 tools, such as gamification (Mayr et al., 2018).

5.9 Summary of the results

The results gathered, coding procedure and validation of scales was detailed in the first section of this chapter. The classification of variables and test of normalcy were described to ensure the correct application of statistical procedures for formal hypothesis testing. The following conclusions are made based on the descriptive and inferential statistical analyses conducted:

1. There is a statistically significant difference in inventory performance for companies with different levels of lean management practice adoption. Hypothesis H-1 is accepted regardless of the absence of a statistically significant correlation between inventory performance and lean inventory management practices
2. There is an inverse relationship between lean inventory management practices and inventory days
3. There is no statistically significant relationship between organisational management and lean inventory management practices at a 0.05 statistical significance level. Hypothesis H-2 is thus rejected
4. There is a statistically significant difference between the median inventory performances for gamified lean inventory management relative to ungamified lean inventory management. Hypothesis H-3 is thus accepted regardless of the absence of a statistically significant correlation between gamification mechanics and inventory performance
5. Organisational employees are the largest barrier to the adoption and implementation of gamified lean inventory management. Hypothesis H-4 is thus rejected
6. 83% of respondents indicated that improving inventory performance to optimise working capital is an organisational strategic objective
7. There is a low awareness of gamification with 34% of respondents familiar with the concept
8. There is no correlation between gamification mechanics and lean inventory management practices at a 0.05 statistical significance level. Hypothesis H-5 is thus rejected.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The overall aim of this quantitative study was to examine the gamification of supply chain inventory management in lean South African petrochemical companies. This study developed detailed conceptual models, based on the extant literature on lean management, gamification and inventory management to identify relationships between the constructs and formulate hypotheses. An appropriate quantitative research methodology was applied to collect data and apply correct quantitative procedures to satisfy the research objectives. The specific research objectives were:

1. Elucidate the relationship between lean inventory management and gamification in SA based petrochemical companies
2. Determine the link between gamified lean inventory management systems and inventory performance (measured as inventory days) in SA based petrochemical companies
3. Identify the quantifiable barriers to adopting and implementing gamified lean inventory management systems in SA based petrochemical companies

Summarised findings of the key results relating to the research objectives will be integrated and concluded upon in this section. Firstly, results pertaining to the elucidation of the link between the prevalence of gamified lean inventory management systems and inventory performance will be presented. Secondly, results for the determination of the inventory performance of gamified lean inventory management systems relative to ungamified lean inventory management systems will be presented. Finally, results identifying and quantifying the barriers to the adoption and implementation of gamified inventory management systems will be presented. Recommendations to key stakeholders, the contribution to knowledge and suggestions for future research will conclude the Chapter.

6.2 The relationship between lean inventory management and gamification in SA based petrochemical companies

The theories underpinning gamification and lean management are change management theory (AlManei et al., 2018), self-determination theory (Koivisto & Hamari, 2019) and the technology acceptance model (Baptista & Oliveira, 2019). This common theoretical basis enabled the development of Hypothesis H-5 which was formulated specifically to determine the relationship between lean inventory management practices and gamification mechanics. Hypothesis H-5 was rejected on the basis that no statistically significant correlation was established between lean inventory management and gamification mechanics. Despite this finding, an exploratory k-means cluster analysis conducted suggests that firms which have a more mature lean inventory management system can adopt more gamification mechanics. This conclusion contributes positively to the perspective that lean inventory management is a prerequisite for introducing Industry 4.0 tools, such as gamification (Mayr et al., 2018).

6.3 The link between gamified lean inventory management systems and inventory performance

Gamification of lean inventory management was proposed as a process innovation (Deterding, 2018) to improve inventory performance by increasing the engagement of actors within the inventory management process. This was based on various literature sources, including AlManei et al. (2018) and Alefari et al. (2017) which emphasised the importance of employee engagement for lean management as well as the effect of gamification on improving engagement (Beck et al., 2019).

There is a statistically significant difference in inventory performance for companies with different levels of lean management practice adoption. Hypothesis H-1 is accepted regardless of the absence of a statistically significant correlation between inventory performance and lean inventory management practices. There is a statistically significant difference between the median inventory performances for gamified lean inventory management relative to ungamified lean inventory management. Hypothesis H-3 is thus accepted regardless of the absence of a statistically significant correlation between gamification mechanics and inventory performance. There is no statistically significant relationship between organisational management and lean inventory management practices so hypothesis H-2 is thus rejected. The exploratory k-means clustering analysis shown in Figure 5-3 suggests that firms with a higher degree of implementation of lean inventory management practices will have lower inventory days, with the inverse also holding.

Taken together, these hypotheses lead to the conclusion that inventory performance is improved by the adoption and implementation of gamified lean inventory management. The combination of lean practices towards eliminating inventory waste by increasing engagement using gamification, enhances the return on lean management.

6.4 Quantification of barriers to the adoption and implementation of gamified lean inventory management systems

Gamification is a new concept relative to lean management. This is clear by analysing and comparing the trends of lean management and gamification publications, shown in Figures 2-4 and 2-5. Top management support, frequently cited as a reason for lean failures, was not a barrier with 83% of respondents indicating that improving inventory performance to optimise working capital is an organisational strategic objective. Together, this suggests that the barriers to the adoption and implementation of gamified inventory management are more likely to be related to gamification.

Considering this, it is concluded that organisational employees are the largest barrier to the adoption and implementation of gamified lean inventory management with the ejection of Hypothesis H-4. This is broadly in agreement with the findings of Alefari et al. (2017) for large companies. This conclusion is underpinned by the low awareness of gamification, with only 34% of respondents familiar with the concept.

6.5 Recommendations

Inventory managers, supply chain practitioners and operations managers can work towards overcoming the organisational employee barrier by investing in training programmes to educate employees on the concept and benefits of gamification to reduce employee resistance. Training and awareness of Industry 4.0 concepts should be considered for inclusion in continuous professional development with support from CHIETA.

Two scales for lean inventory management practices and gamification mechanics were developed, validated and tested for reliability towards the process of meeting the research objectives. These scales can be used by academics for further research in gamification and lean inventory management. Practitioners such as supply chain professionals can also use these scales for internally and externally benchmarking their supply chain.

6.6 Contribution to knowledge

This research contributes to knowledge by generating practice insights into lean inventory management and gamification. Furthermore, the study advances the theoretical agenda of determining the pre-determinants of gamification success

(Koivisto & Hamari, 2019), and whether lean management is a prerequisite for adopting Industry 4.0 tools (Mayr et al., 2018). This research also extends the knowledge base of lean and gamification to the South African context.

6.7 Suggestions for further research

Aside from developing measurement scales for lean inventory management practices and gamification mechanics, this research has provided more opportunities for further research. The following suggestions are made for future research:

1. Consider using the empirical leanness indicator defined by Eroglu and Hofer (2011) to cater for the effect of economies of scale on inventory performance
2. Investigate the effect of firm size and process type on gamified lean inventory performance (Demeter & Matyusz, 2011)
3. The reliability of the results can be improved by directly obtaining inventory performance data from company archives to eliminate the risk of respondent perception bias of their company performance.
4. Focus the research frame on small, micro and medium enterprises within the petrochemical sector
5. Investigating the effect of player type on the adoption and success of gamification of inventory management systems
6. Consider the impact of the external environment on the prevalence and barriers to adoption of gamification of lean inventory management
7. Conduct a longitudinal study to enhance temporal validity
8. Conduct a controlled experiment inclusive of a simulation exercise to compensate for low prevalence of familiarity of gamification

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APPENDIX A: CONSISTENCY MATRIX

Problem Statement: Finished goods, work in progress and raw materials inventory management is an important contributor to improving the financial sustainability of a firm. Schonberger (2019), argues that inventory performance has been deteriorating globally since the beginning of the new millennium, negatively impacting financial sustainability of firms. This research primarily aims to elucidate the relationship between inventory performance and gamified inventory management systems. Secondary research aims are to identify quantifiable barriers to adopting and implementing gamified inventory management systems for improving and sustaining inventory performance of the SA petrochemical sector.

Sub-problem	**Literature articles reviewed**	**Hypotheses**	**Means of data collection**	**Methodology and data collection**	**Method of data analysis**
Prevalence of gamified lean inventory management	(Mayr et al., 2018) (Nacke & Deterding, 2017) (Vukadinovic et al., 2018)	H0-3; H-3	Survey questionnaire	Primary data obtained by random purposive sampling	Descriptive statistics
Inventory performance	(Eroglu & Hofer, 2011) (Demeter & Matyusz, 2011)	H0-1; H-1	Survey questionnaire		Descriptive statistics

Problem Statement: Finished goods, work in progress and raw materials inventory management is an important contributor to improving the financial sustainability of a firm. Schonberger (2019), argues that inventory performance has been deteriorating globally since the beginning of the new millennium, negatively impacting financial sustainability of firms. This research primarily aims to elucidate the relationship between inventory performance and gamified inventory management systems. Secondary research aims are to identify quantifiable barriers to adopting and implementing gamified inventory management systems for improving and sustaining inventory performance of the SA petrochemical sector.					
Sub-problem	**Literature articles reviewed**	**Hypotheses**	**Means of data collection**	**Methodology and data collection**	**Method of data analysis**
Correlation analysis	(Rowley, 2014) (Welman et al., 2005) (Demeter & Matyusz, 2011) (Eroglu & Hofer, 2011) (Gilbert & Prion, 2016) (Harpe, 2015) (Boone & Boone, 2012) (Gilbert & Prion, 2016)	H0-1; H-1; H0-2; H-2; H0-3; H-3; H0-4; H-4; H0-5; H-5;	Survey questionnaire	Primary data obtained by random purposive sampling	Inferential statistics and hypothesis testing

Problem Statement					
Problem Statement: Finished goods, work in progress and raw materials inventory management is an important contributor to improving the financial sustainability of a firm. Schonberger (2019), argues that inventory performance has been deteriorating globally since the beginning of the new millennium, negatively impacting financial sustainability of firms. This research primarily aims to elucidate the relationship between inventory performance and gamified inventory management systems. Secondary research aims are to identify quantifiable barriers to adopting and implementing gamified inventory management systems for improving and sustaining inventory performance of the SA petrochemical sector.					
Sub-problem	**Literature articles reviewed**	**Hypotheses**	**Means of data collection**	**Methodology and data collection**	**Method of data analysis**
Identification of barriers to adoption and implementation	(Mayr et al., 2018) (Nacke & Deterding, 2017) (Vukadinovic et al., 2018)' (Sweeney et al., 2015) (Rane et al., 2014) (Alefari et al., 2017) (AlManei et al., 2018)	H0-2; H-2; H0-4; H-4	Survey questionnaire		Descriptive statistics
Recommendations			None		Content analysis

APPENDIX B: RESEARCH INSTRUMENT

SurveyMonkey © has been used to design and online survey questionnaire. Respondents can answer the survey on their mobile forms or computers.

The gamification of inventory management in South African petrochemical refineries

A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfillment of the requirements for the degree of Master of Management in the field of Digital Business

Next

Powered by SurveyMonkey

The gamification of inventory management in South African petrochemical refineries

Informed consent

Thank you for participating in our survey. Your feedback is important.

PLEASE NOTE: The survey can be answered online using a mobile device or computer

By proceeding with this survey, the respondent hereby gives permission to the primary researcher, Meli Mashinini of the Wits Business School, University of Witwatersrand, the following:

1. To engage (survey) the respondent as an employee representative of a company

2. To collect and publish information about the company which may not be publicly available

for the research project titled: The gamification of inventory management in South African petrochemical refineries

This authorisation is based on the mutual understanding that the results specific to the above mentioned company's name will not be revealed in this project. Additionally, information gathered in this project will not enable a third party to identify the name of the above mentioned company as a respondent to the survey. The information provided by the employees or any other means (such as company's archived documents or reports) of the above mentioned company is purely for academic purposes and cannot be used for any other purpose. The researcher will strive to ensure anonymity and confidentiality are protected.

Prev Next

The gamification of inventory management in South African petrochemical refineries

Lean inventory management

Definition of key terms

Lean management: The elimination of waste in the value chain through continuous improvement, maximising customer satisfaction

Lean inventory management: The application of lean principles and practices in the management of inventory

Inventory performance (leanness): The days of inventory of finished goods held by the firm

* 1. Your organisation views inventory as waste which needs to be minimized

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 2. Customer value focus drives decision making in the inventory management process

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 3. Employees are empowered to take decisions to improve inventory performance

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 4. The organisational culture supports the continuous improvement of inventory performance

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 5. The organisation aims to reduce the complexity of the inventory management process

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 6. The goal is the pursuit of perfection of inventory performance

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Stronlgy agree

Prev Next

The gamification of inventory management in South African petrochemical refineries

Gamification of lean inventory management

Definition of key terms

Gamification: The use of game design elements in non-game contexts

* 7. Are you familiar with the concept of gamification, where game-design elements are used in non-game contexts to improve employee engagement?

- ◯ Yes
- ◯ No

* 8. Gamified processes have at least one of the below mechanics. Please select the mechanics present in your inventory management process

- ☐ Leaderboards, badges and points
- ☐ Increasing task difficulty
- ☐ Finite end
- ☐ Multiplayer orientation
- ☐ Infinite play
- ☐ New levels
- ☐ Team playing
- ☐ Online playing
- ☐ Real world playing
- ☐ None of the above

The gamification of inventory management in South African petrochemical refineries

Identification of barriers

Definition of key terms

Functional controls

Organisational strategy: The organisation's long term goals and objectives in pursuit of fulfilling its vision

Industry standards: The applicable industry standards which provide best practices on lean management principles

Applicable regulations: The applicable regulations which need to be complied with in order to secure a licence to operate

Lean inventory management practices: The feasibility of implementing lean inventory management best practices. Specific practices are identification and elimination of waste, employee empowerment, continuous improvement and customer focus

Gamification practices: The feasibility of implementing the 9 gamification mechanics

* 9. Organisational strategy is a barrier to gamified lean inventory management in my organisation

- ◯ Strongly disagree
- ◯ disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly Agree

* 10. Industry standards are a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- disagree
- Neither agree nor disagree
- Agree
- Strongly Agree

* 11. Applicable regulations are a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- disagree
- Neither agree nor disagree
- Agree
- Strongly Agree

* 12. Lean inventory management practices are a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- disagree
- Neither agree nor disagree
- Agree
- Strongly Agree

* 13. Gamification practices are a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- disagree
- Neither agree nor disagree
- Agree
- Strongly Agree

The gamification of inventory management in South African petrochemical refineries

Organisational management

Definition of key terms

Organisational management

Human resource management: The degree to which planning, organisation, leading and controlling (POLC) of employees enables lean inventory management

Management focus: The degree to which management has a strategic versus tactical focus

Change management: The degree of competence in POLC of business transformations enables lean inventory management

Lean inventory management: The degree of competence in POLC the process of optimising the flow of raw materials, finished products and work in process materials in order to minimize waste while meeting customer requirements

Human-machine interface management: The degree to which management has competence in POLC of human-machine interfaces enables gamified lean inventory management

Digital transformation: The degree to which management has the competence to POLC digital transformations

* 14. Human resource management is a barrier to gamified lean inventory management in my organisation

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

* 15. Management focus is a barrier to gamified lean inventory management in my organisation

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

* 16. Change management is a barrier to gamified lean inventory management in my organisation

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

* 17. Human-machine interface management is a barrier to gamified lean inventory management in my organisation

- ◯ Strongly disagree
- ◯ Disagree
- ◯ Neither agree nor disagree
- ◯ Agree
- ◯ Strongly agree

* 18. Digital transformation management is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 19. Lean inventory management is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

The gamification of inventory management in South African petrochemical refineries

Organisational employees

Definition of key terms

Employee resistance: The degree to which an employee displays inertia to change

Employee training: The quality and quantity of training interventions undertaken to improve the effectiveness and efficiency of lean inventory management

Employee education level: The education level of an employee based on the South African NQF level

Employee motivation: The degree to which an employee undertakes a task with direction, intensity and persistence

* 20. Employee resistance is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 21. Employee training is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 22. Employee education level is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 23. Employee motivation is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

The gamification of inventory management in South African petrochemical refineries

Organisational infrastructure

Definition of key terms

Software and computer infrastructure: The support software and computer systems required to enable the management of the lean inventory management program

Hardware and facilities: The physical tools, facilities and environmental layout of the equipment which impact on employees' ease of executing lean inventory management

Industry 4.0 technologies: The Industry 4.0 technologies required to enable the gamification of lean inventory management

Performance management system: The degree to which the existing performance management system enables the gamification of inventory management

* 24. Software and computer infrastructure is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 25. Hardware and facilities is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 26. Industry 4.0 technologies is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

* 27. The performance management system is a barrier to gamified lean inventory management in my organisation

- Strongly disagree
- Disagree
- Neither agree nor disagree
- Agree
- Strongly agree

The gamification of inventory management in South African petrochemical refineries

* 28. Are you involved in the inventory management process of your organisation?

- Yes
- No

* 29. Which function do you work for in your organization?

- Supply chain
- production planning
- demand/ sales planning
- operations

* 30. How many years of inventory management experience do you have?

* 31. What is the inventory performance of your organisation in days of inventory?

0 365

* 32. Is improving inventory performance to optimise working capital a strategic objective in your organisation?

- Yes
- No

* 33. What is the annual revenue of your company in ZAR Millions?

34. Please provide your e-mail adress if you wish to get feedback on this study

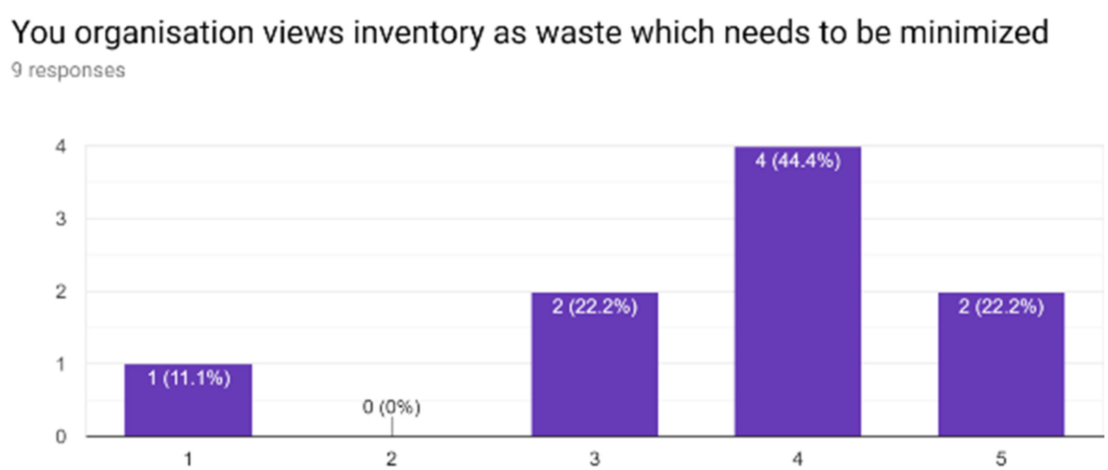
Prev Done

APPENDIX C: QUESTIONNAIRE PRE-TEST RESULTS

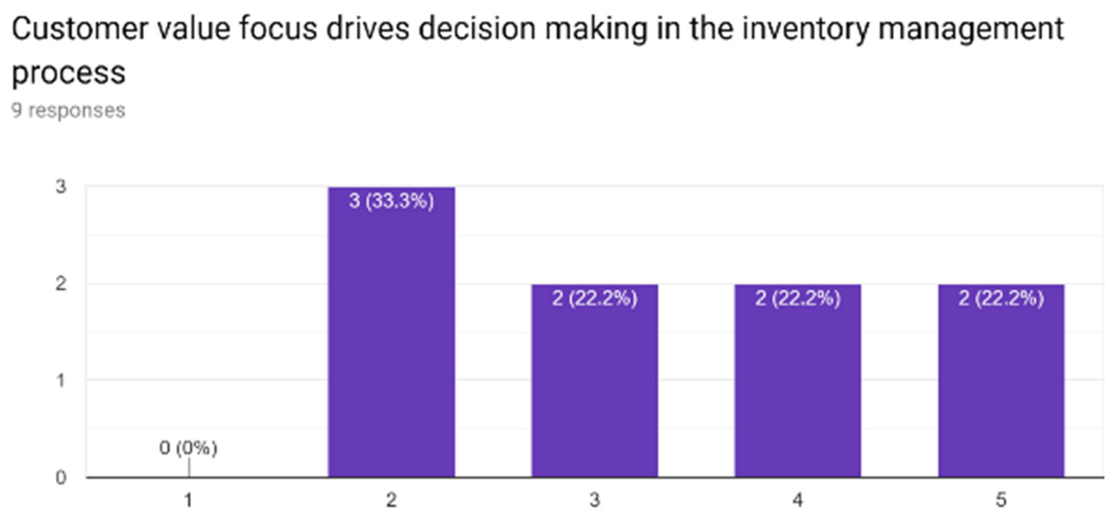
In general, the pre-test results were acceptable, and no major changes are required to the questionnaire which would justify another pre-test.

C.1 Lean inventory management

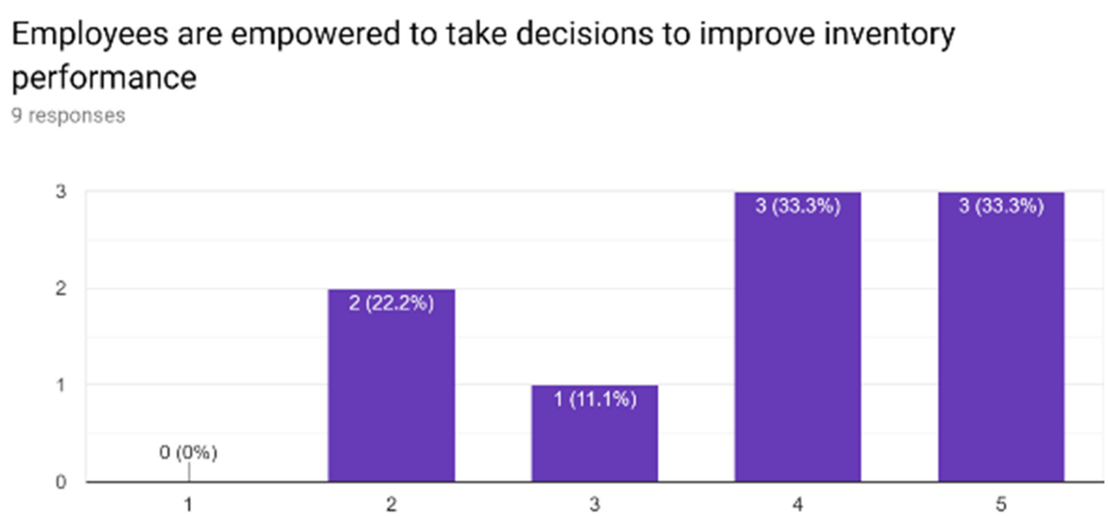
The purpose is to determine whether the respective firms are managing inventory in a lean way – with a goal of optimising and ideally eliminating inventory waste. This subset of questions will be tested using Cronbach's alpha. Likert-type scale from strongly disagree to strongly agree



Consider defining waste – want to keep question length short, but respondents also are overwhelmed by the long definitions page at the start of the questionnaire



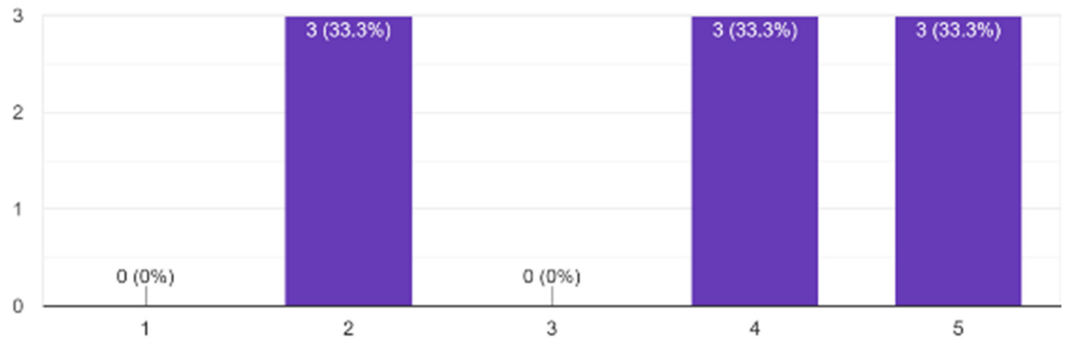
The distribution is non-normal, may improve with additional samples. For this distribution I would need to use Kruskal-Wallis and spearman's rho. The data will be aggregated so will go from ordinal to interval, can then use parametric tests like ANOVA and Pearson's correlation



Non-normal distribution

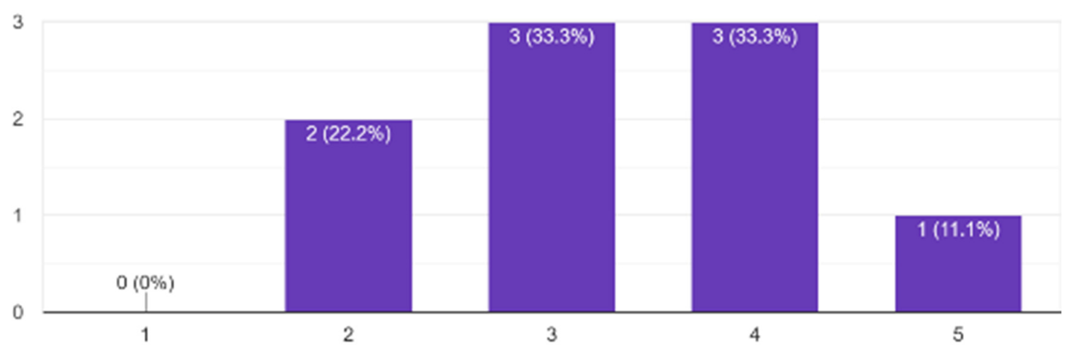
The organisational culture supports the continuous improvement of inventory performance

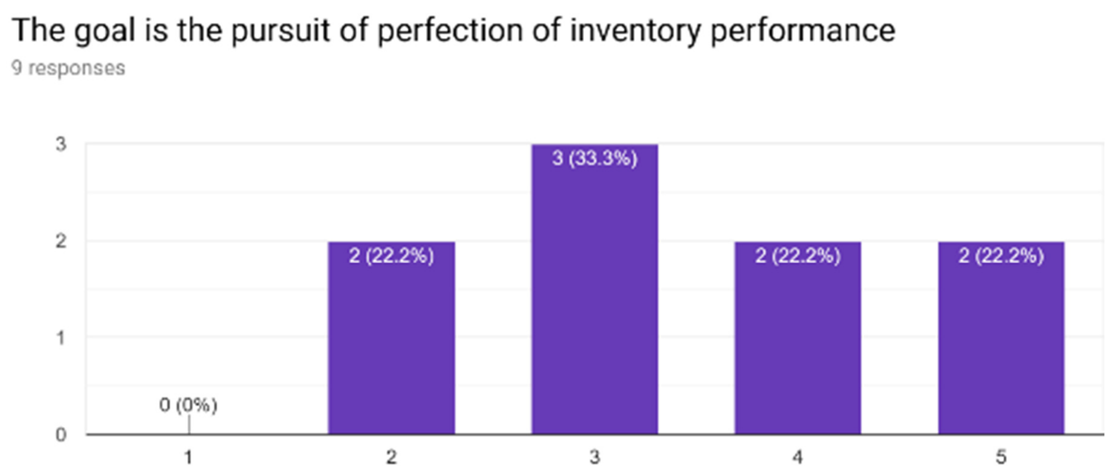
9 responses



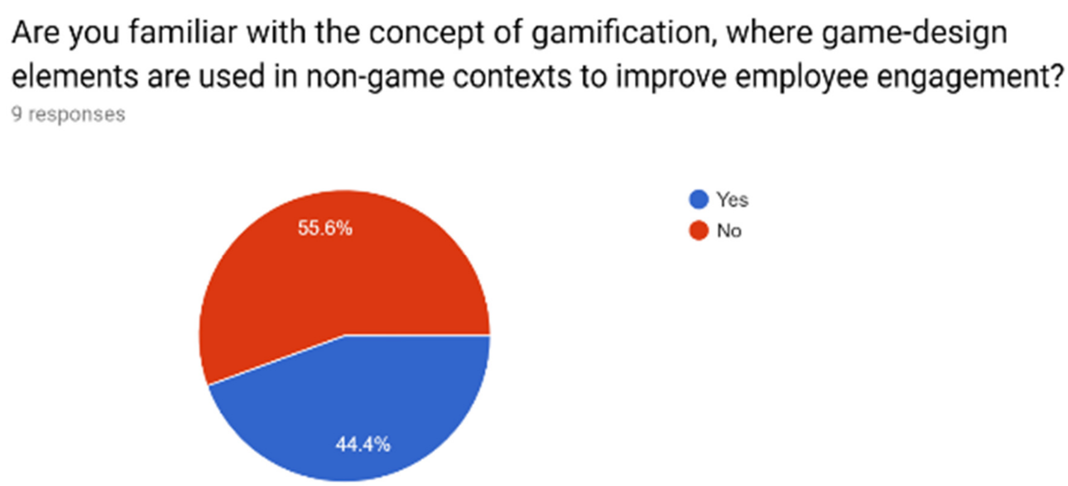
The organisation aims to reduce the complexity of the inventory management process

9 responses

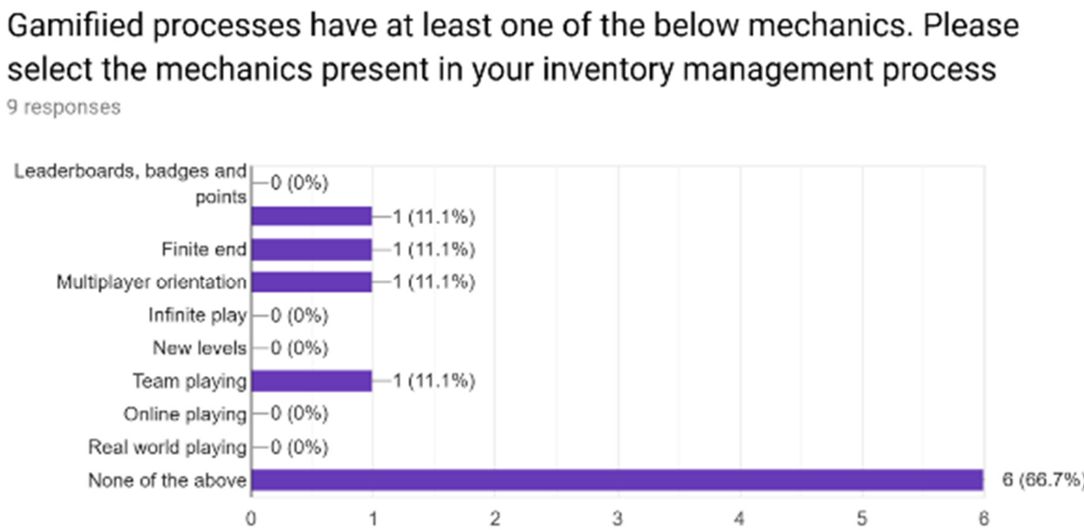




C.2: Gamification of lean inventory management



In the final report, a pie chart will not be used. Results will be summarised in a sentence.



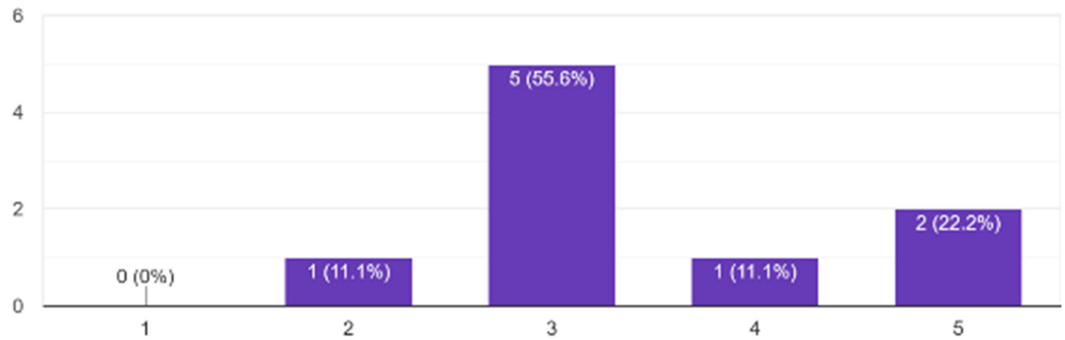
Most company respondents don't have gamification mechanisms so hypothesis testing that gamified inventory systems outperform ungamified systems may not be feasible. From a coding perspective, the question allows multiple selection of gamification elements. The more elements selected, the more gamified the processes and the higher probability that gamification will cover different player types per self-determination theory.

C.3 Identification of barriers

In general, there were a lot of "neutral" answers – which indicates that respondent's either are indeed neutral, or don't know. From the literature, adding a "don't know" response option is unlikely to improve response quality.

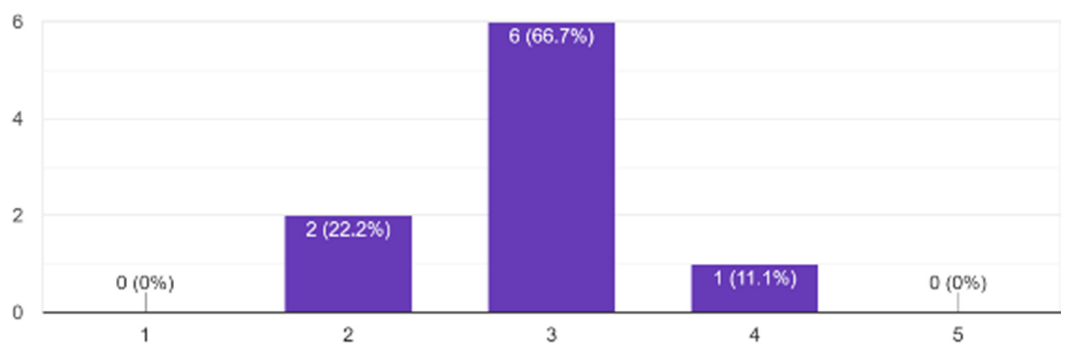
Organisational strategy is a barrier to gamified lean inventory management in my organisation

9 responses



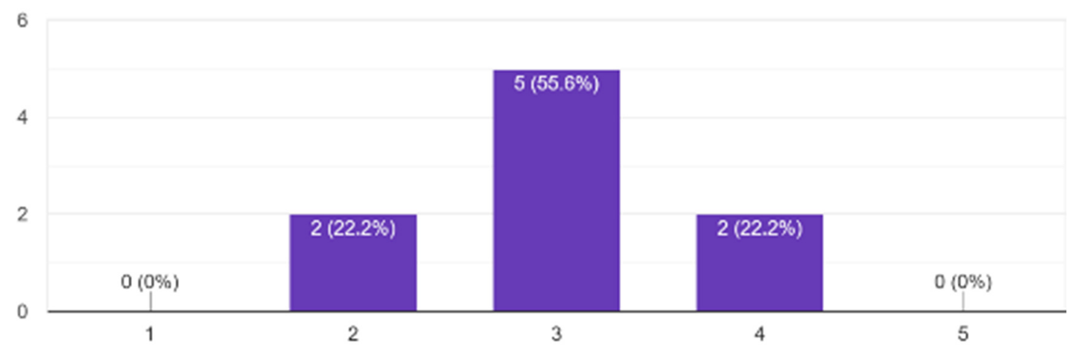
Industry standards are a barrier to gamified lean inventory management in my organisation

9 responses



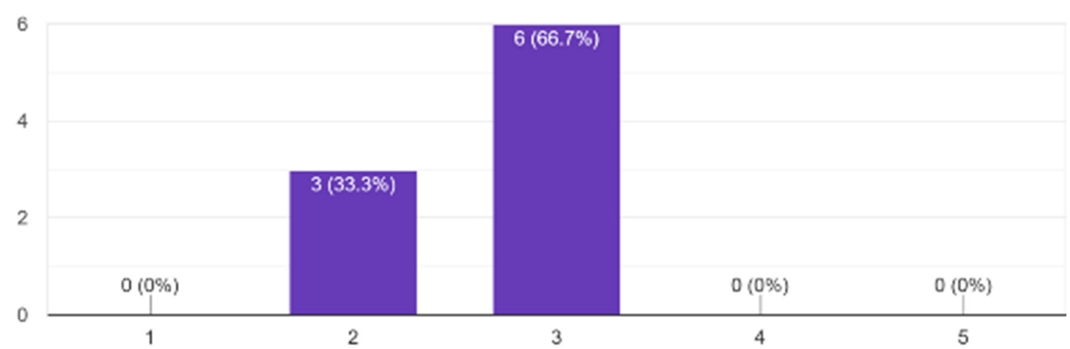
Applicable regulations are a barrier to gamified lean inventory management in my organisation

9 responses



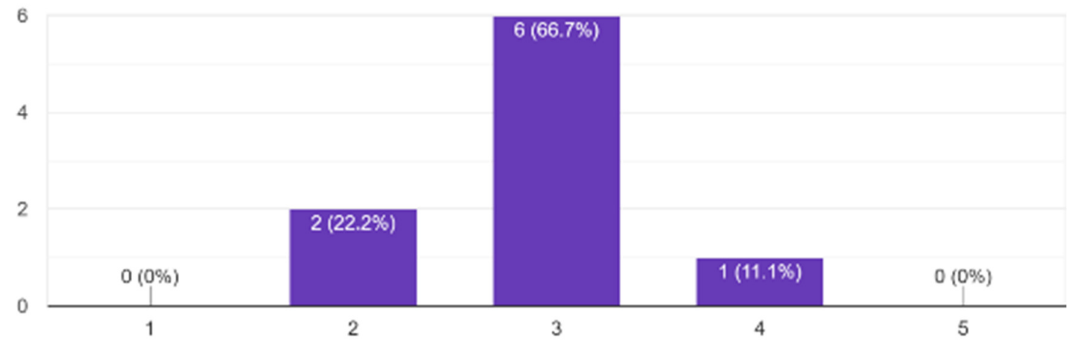
Lean inventory management practices are a barrier to gamified lean inventory management in my organisation

9 responses



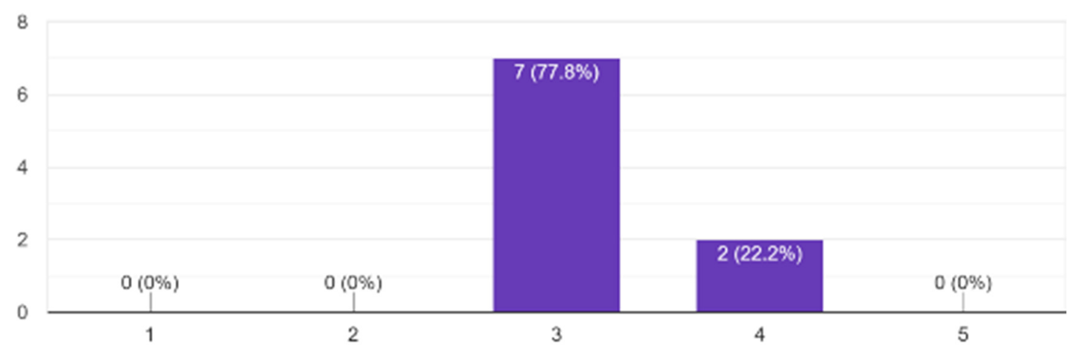
Gamification practices are a barrier to gamified lean inventory management in my organisation

9 responses



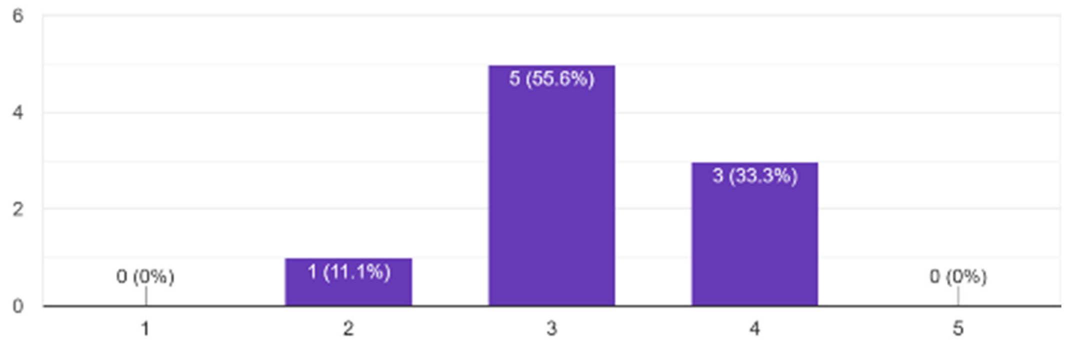
Human resource management is a barrier to gamified lean inventory management in my organisation

9 responses



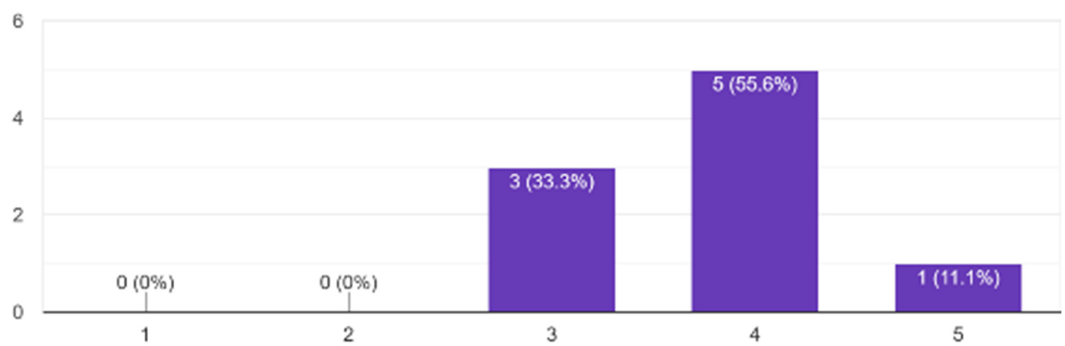
Management focus is a barrier to gamified lean inventory management in my organisation

9 responses



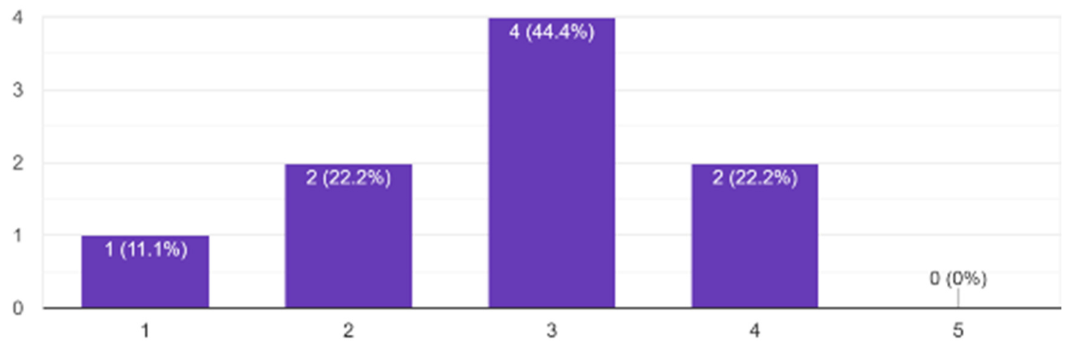
Change management is a barrier to gamified lean inventory management in my organisation

9 responses



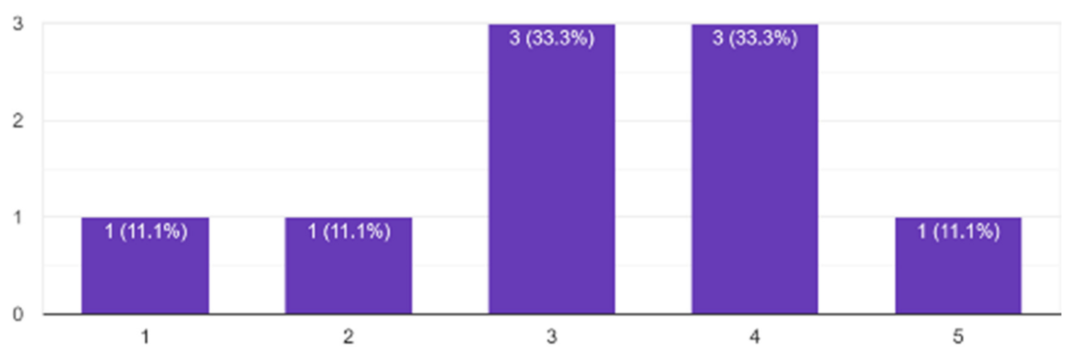
Human-machine interface management is a barrier to gamified lean inventory management in my organisation

9 responses



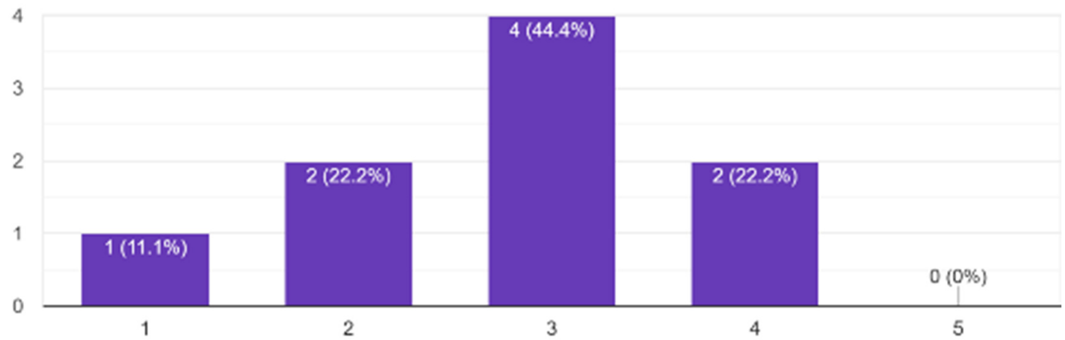
Digital transformation management is a barrier to gamified lean inventory management in my organisation

9 responses



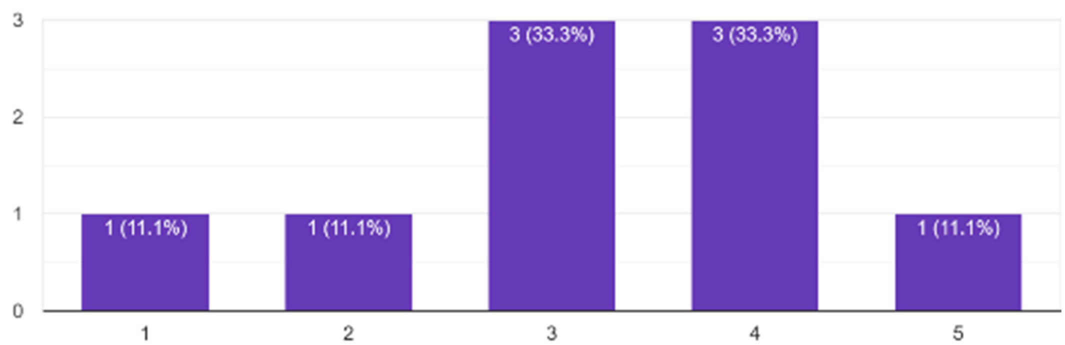
Lean inventory management is a barrier to gamified lean inventory management in my organisation

9 responses



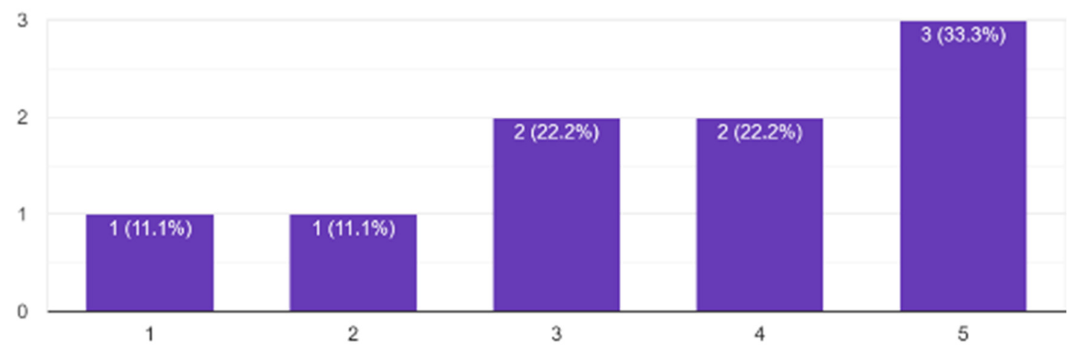
Employee resistance is a barrier to gamified lean inventory management in my organisation

9 responses



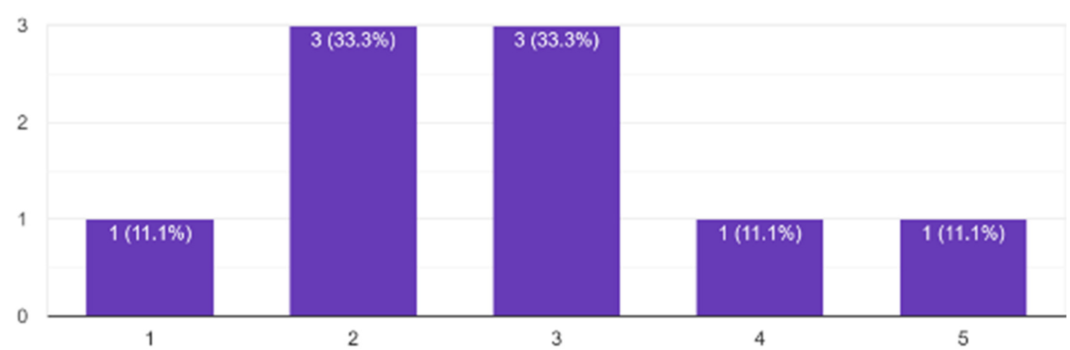
Employee training is a barrier to gamified lean inventory management in my organisation

9 responses

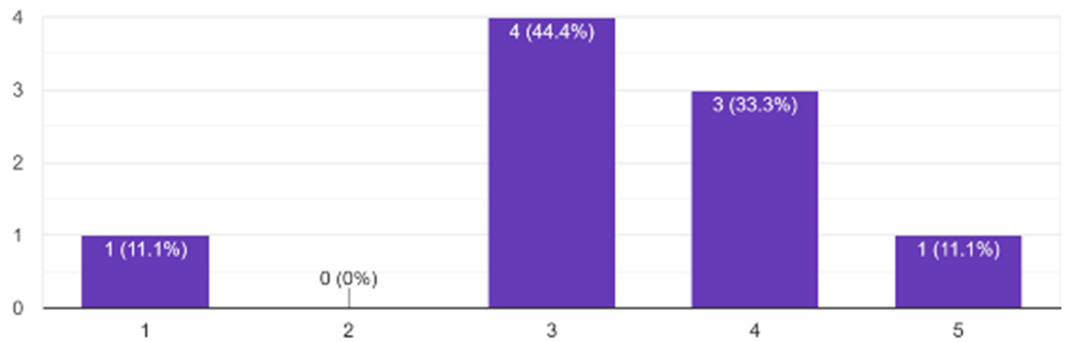


Employee education level is a barrier to gamified lean inventory management in my organisation

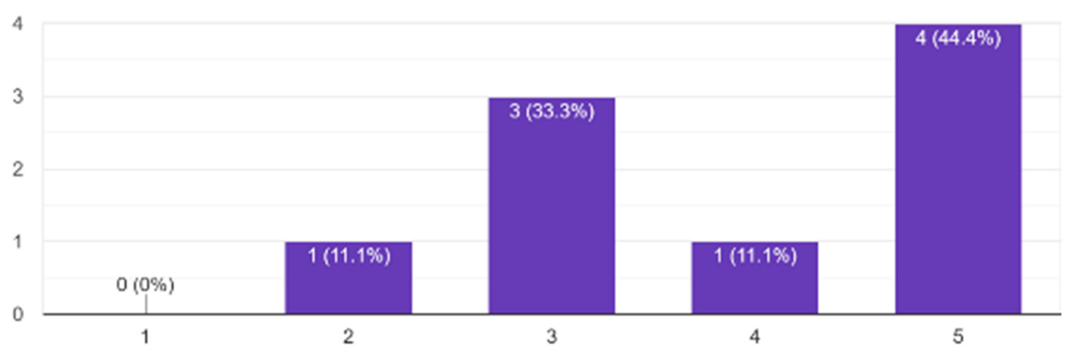
9 responses

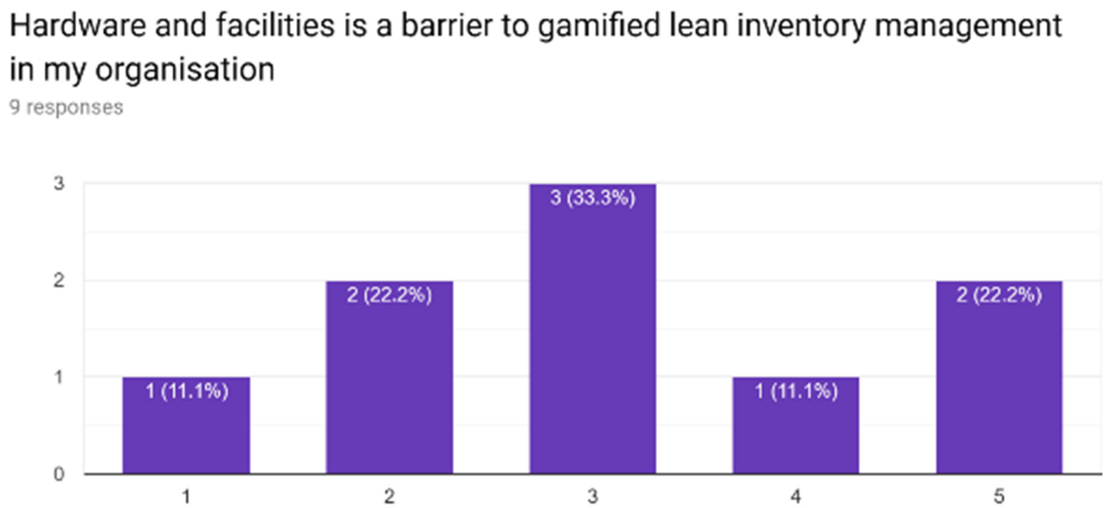


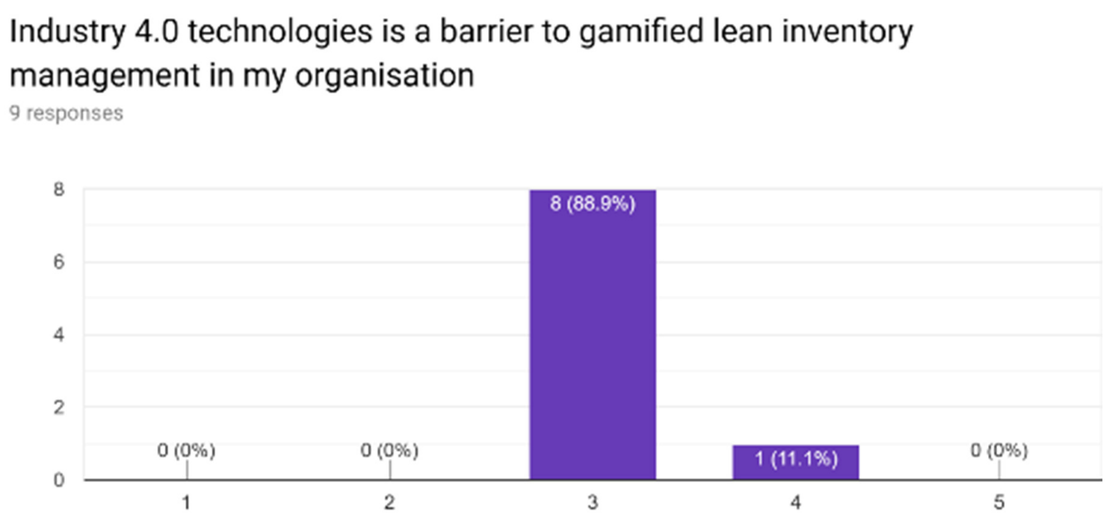
Employee motivation is a barrier to gamified lean inventory management in my organisation
9 responses



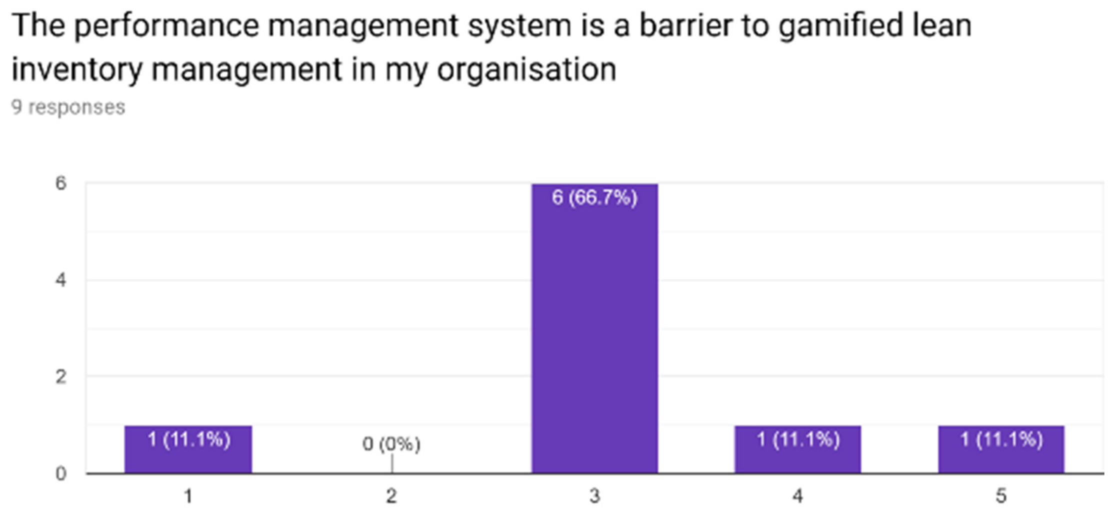
Software and computer infrastructure is a barrier to gamified lean inventory management in my organisation
9 responses



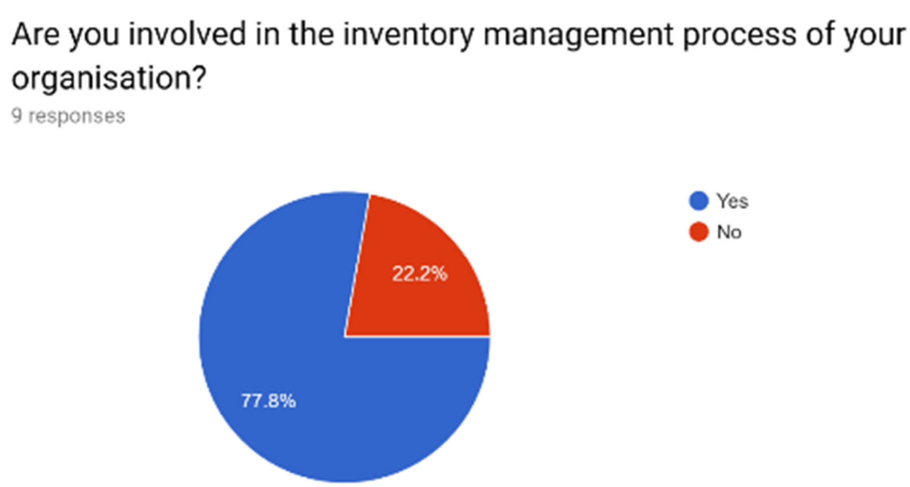




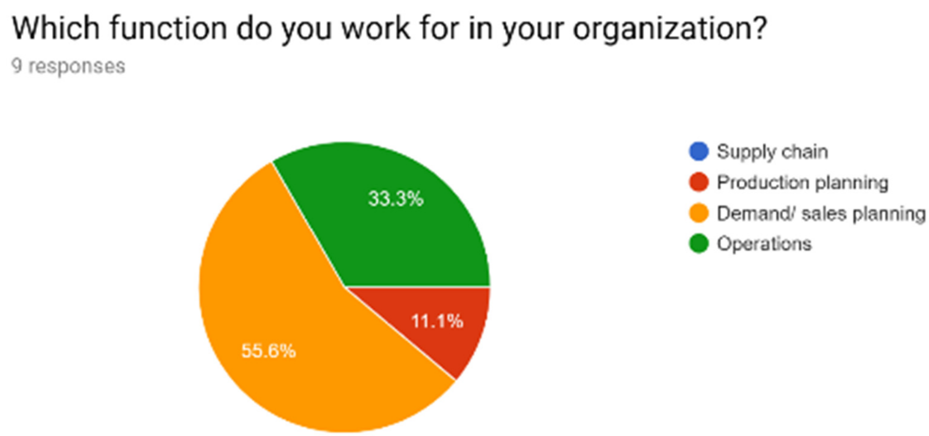
High number of neutral responses may indicate that respondents don't know what Industry 4.0 technologies are – although this was in the (long) list of key definitions



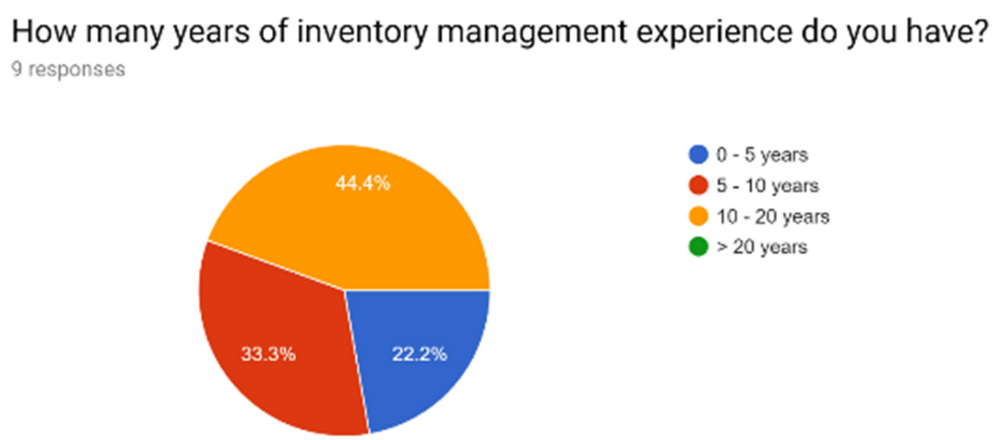
C.4 General Information

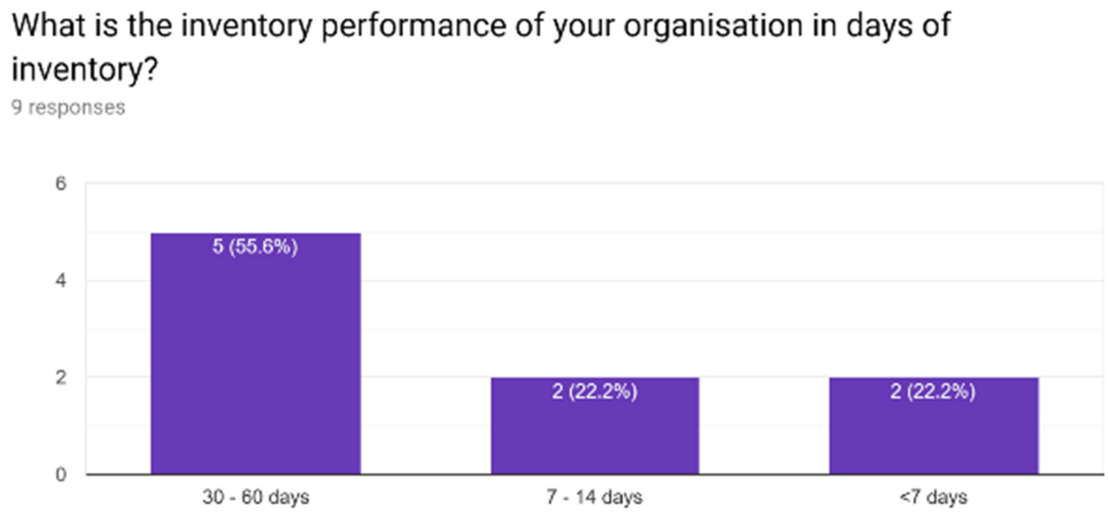


2 of 11 respondents indicated they are not directly involved in inventory management; this however doesn't improve the general trend of responses and departure from normalcy

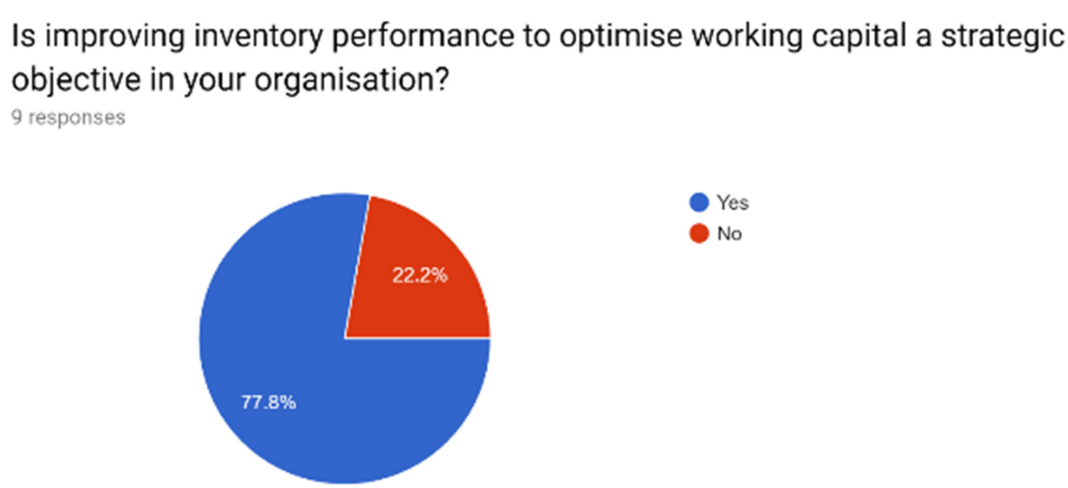


Good spread of respondents but no supply chain representation – this is due to the convenience sampling for pre-testing

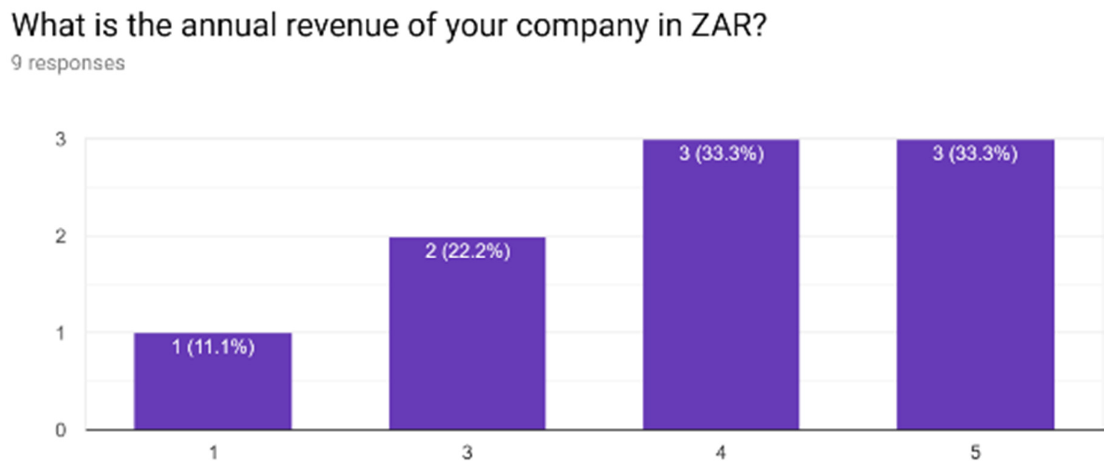




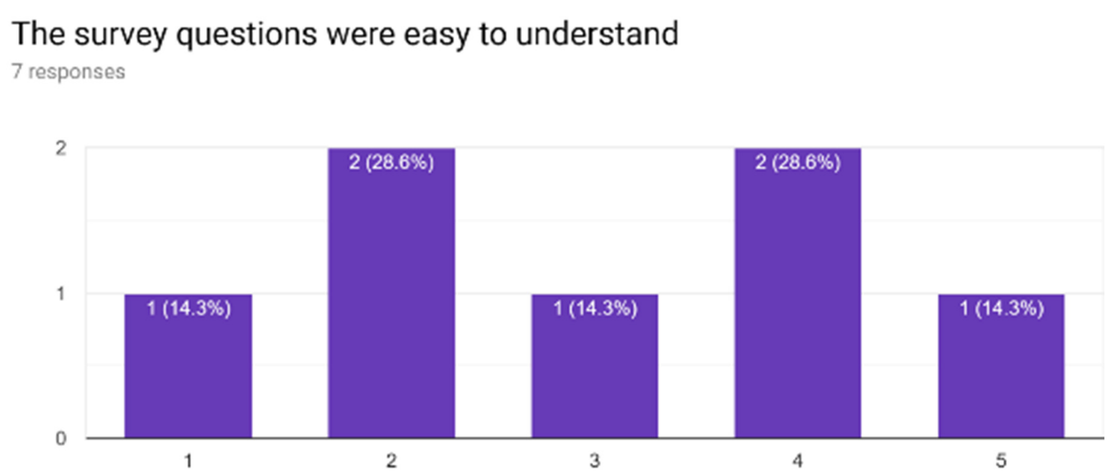
The inventory performance needs to be more exact to enable better comparison with the OSIRIS database. This scale will be changed to a continuous scale/ free text input. According to the OSIRIS database, the days of sale for the top 50 integrated petroleum companies is 24 days so the majority of companies are below this benchmark



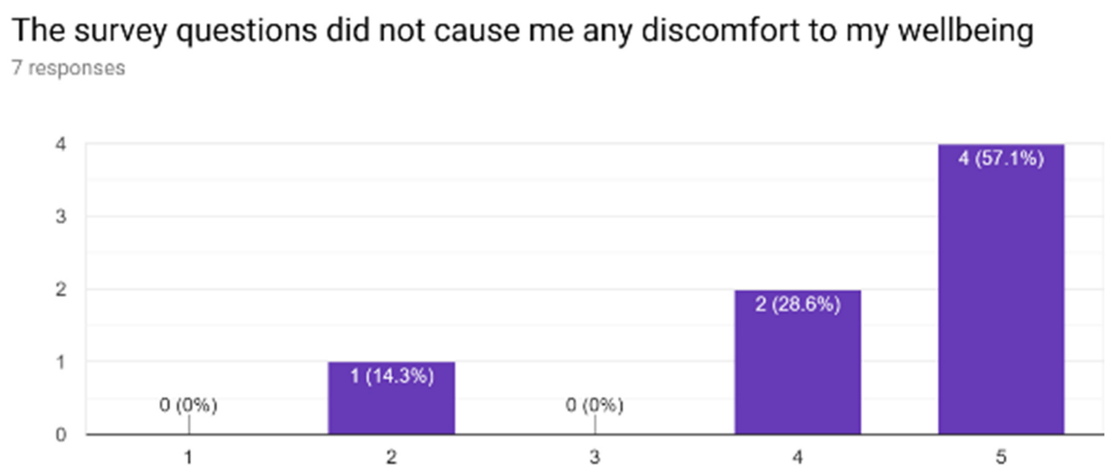
Relates to the strategic barrier reasonably well



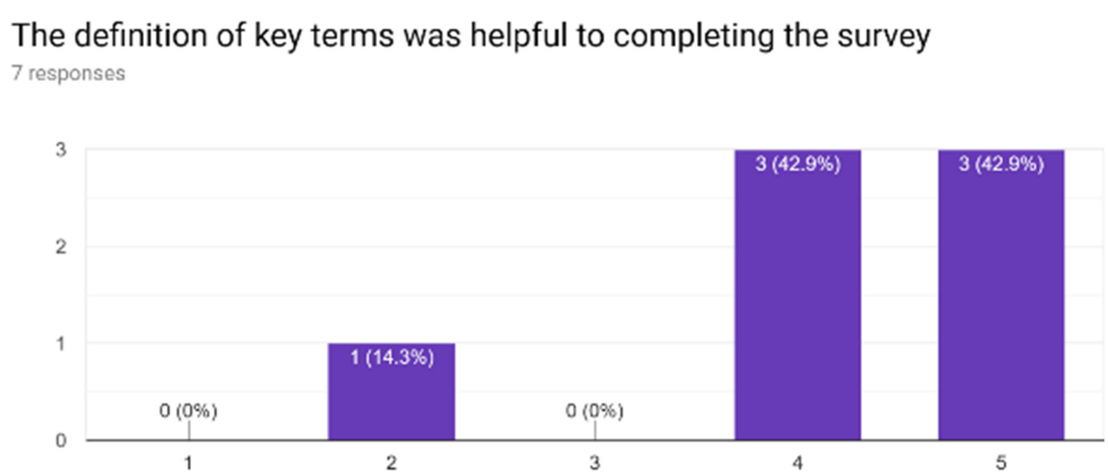
This question was modified after the pre-test. Original question relates to the self-reported supply chain complexity from simple to complex. This measure was too subjective to be easily comparable with the OSIRIS database. Question will be changed to turnover in order to use turnover as a proxy for complexity.



Some difficulty in asking the questions – the questions with a high number of neutral responses are most likely to have been perceived as the most difficult



One respondent felt discomfort due to them not being aware of gamification and being frustrated by having to answer gamification related questions.



Key terms were generally deemed to be helpful but can perhaps be made more succinct

APPENDIX D: CONSTRUCTION OF MEASUREMENT SCALES

D.1 CONSTRUCTION AND VALIDATION OF SCALES

Cronbach alpha for lean inventory management practices scale

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.697	.716	6

Cronbach alpha is borderline acceptable as it is just below 0.7 (Gliem & Gliem, 2003)

Item number 1 has low inter-item correlation so can likely be deleted to improve reliability further

Inter-Item Correlation Matrix

	Your organisation views inventory as waste which needs to be minimized	Customer value focus drives decision making in the inventory management process	Employees are empowered to take decisions to improve inventory performance	The organisational culture supports the continuous improvement of inventory performance	The organisation aims to reduce the complexity of the inventory management process	The goal is the pursuit of perfection of inventory performance
Your organisation views inventory as waste which needs to be minimized	1.000	-.082	-.052	-.023	-.157	-.103
Customer value focus drives decision making in the inventory management process	-.082	1.000	.426	.410	.564	.589
Employees are empowered to take decisions to improve inventory performance	-.052	.426	1.000	.596	.455	.205
The organisational culture supports the continuous improvement of inventory performance	-.023	.410	.596	1.000	.633	.401

Inter-Item Correlation Matrix

	Your organisation views inventory as waste which needs to be minimized	Customer value focus drives decision making in the inventory management process	Employees are empowered to take decisions to improve inventory performance	The organisational culture supports the continuous improvement of inventory performance	The organisation aims to reduce the complexity of the inventory management process	The goal is the pursuit of perfection of inventory performance
The organisation aims to reduce the complexity of the inventory management process	-.157	.564	.455	.633	1.000	.580
The goal is the pursuit of perfection of inventory performance	-.103	.589	.205	.401	.580	1.000

Item-Total statistics

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Your organisation views inventory as waste which needs to be minimized	17.23	18.965	-.106	.036	.823

Item-Total Statistics

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Customer value focus drives decision making in the inventory management process	16.52	13.172	.586	.472	.603
Employees are empowered to take decisions to improve inventory performance	16.74	13.408	.496	.425	.632
The organisational culture supports the continuous improvement of inventory performance	16.73	12.825	.638	.533	.585
The organisation aims to reduce the complexity of the inventory management process	17.18	13.296	.649	.573	.589
The goal is the pursuit of perfection of inventory performance	16.90	14.253	.498	.465	.636

Cronbach alpha increases to 0.823 if item 1 is deleted resulting in an acceptable scale result. This is due to the poor inter-item correlation of item 1. Item 1 may have been ambiguous due to the use of the term waste. In order to improve item correlation in future, it is recommended that waste is defined upfront to survey respondents to improve consistency of understanding. The lean inventory management scale will be adjusted to delete item 1 in order to improve the reliability of the measure for further analysis.

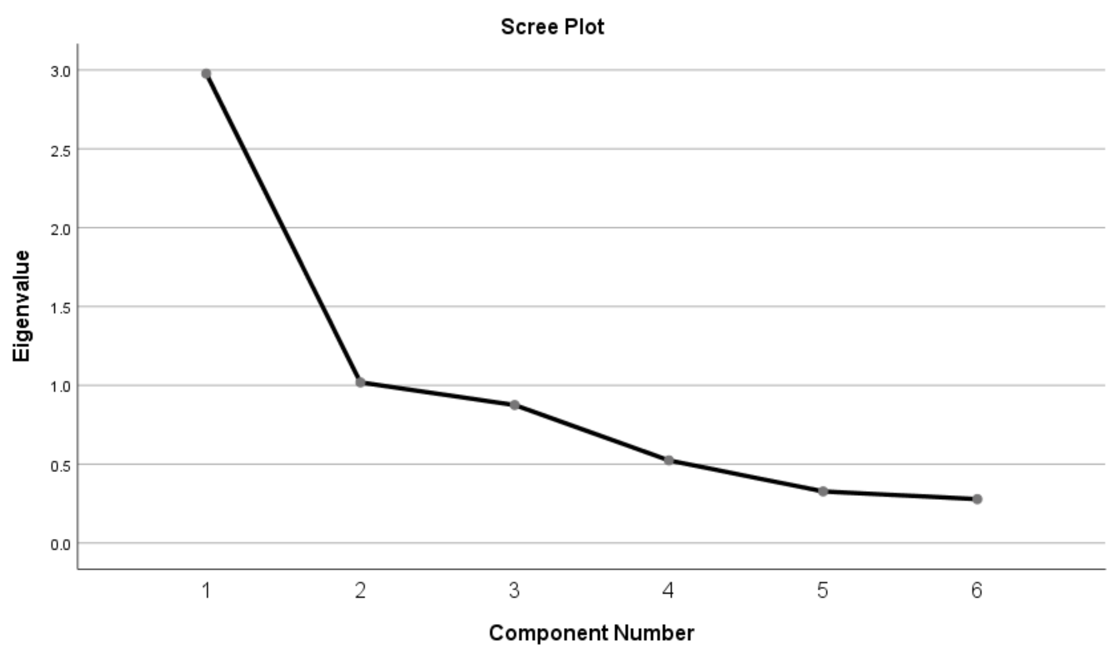
Factor analysis

Component correlation matrix rotation method requires an absolute correlation value greater than 0.32 to be deemed appropriate, hence no rotation was applied

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.741
Bartlett's Test of Sphericity	Approx. Chi-Square	120.241
	df	15
	Sig.	.000

KMO test above 0.7 is acceptable at a statistical significance level less than 0.001



From the scree-plot, eigenvalues above one can be separated as different factors. This shows that item 1 is an outlier which should be excluded from the summated scale

Reliability of gamification scale

The construct is summated from dichotomous items. The logical justification is that the more gamification mechanics present, the higher the extent of gamification. The maximum possible summated item score is 9, which is the score if all gamification mechanics are present. The minimum score is 0, which reflects that no gamification mechanics are present. In order to establish the reliability of the construct statistically, the intraclass correlation coefficient (ICC) is be applied. According to Koo and Li (2016), a two-way mixed effects model with a single measurement and absolute agreement is appropriate for a test-retest reliability study. After administering the survey, respondents who indicated that they would like to receive survey feedback, were requested to take part in a re-test survey only focused on the gamification mechanics. In total, 22 surveys were distributed, and 9 responses were received for a response rate of 41%. The survey was distributed between 2 and 4 weeks after respondents had taken the full survey.

The intraclass correlation coefficient for the average measure is 0.921 at a statistical significance level of 0.001 and 95% confidence interval which is interpreted as excellent (Gliem & Gliem, 2003)

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	.854[a]	.489	.965	11.769	8	8	.001
Average Measures	.921[c]	.656	.982	11.769	8	8	.001

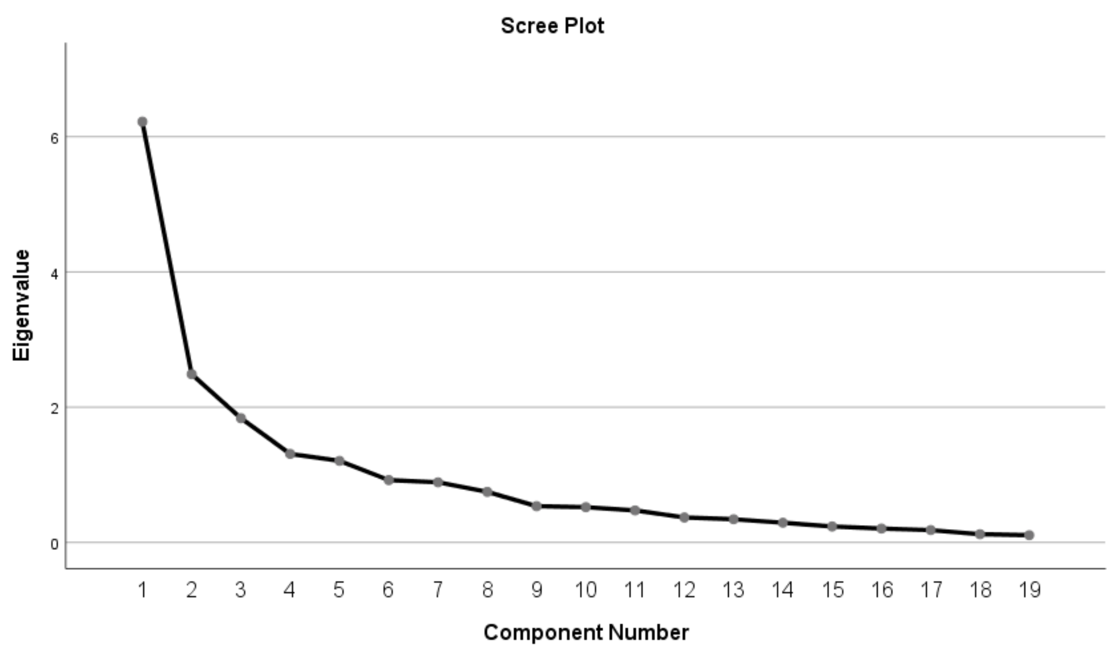
Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type A intraclass correlation coefficients using an absolute agreement definition.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Factor analysis for barriers

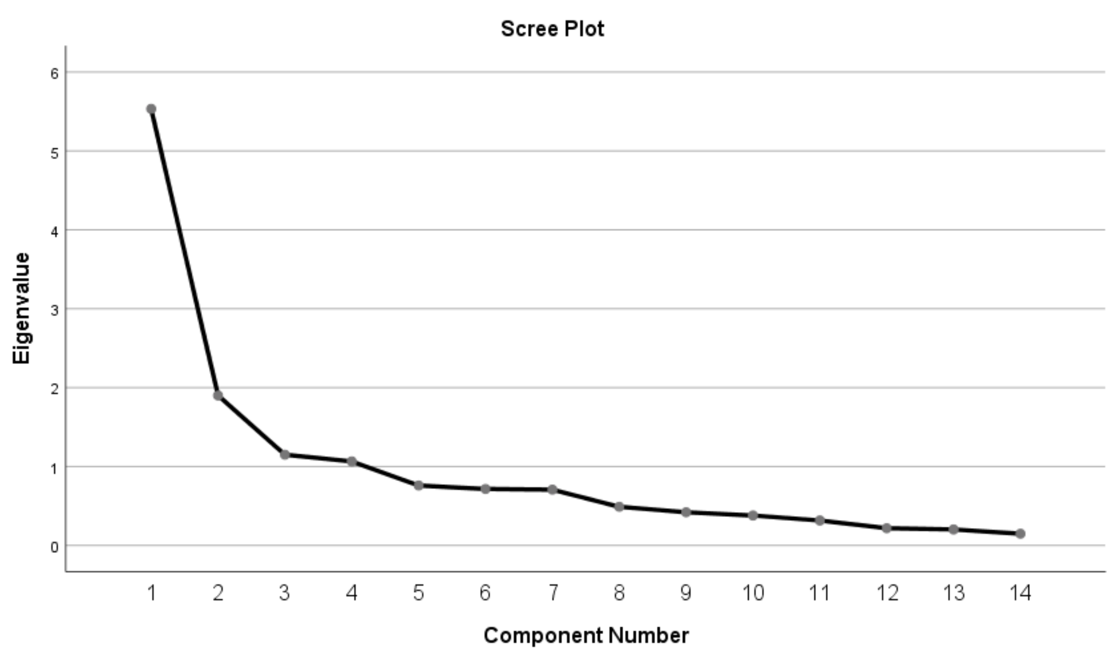


As shown above, Items 1 to 5 can be reduced to form 1 constructs as the eigenvalues are above 1. These 5 items correspond with the controls shown in the IDEF0 for adopting and implementing gamified lean inventory management.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.798	.809	5

The Cronbach alpha for the resultant scale of items 1 to 5 is acceptable as it is greater than 0.7 (Gliem & Gliem, 2003). Factor analysis is conducted again after removing the 5 components grouped into the single construct for the controls governing the adoption and implementation of gamified lean inventory management

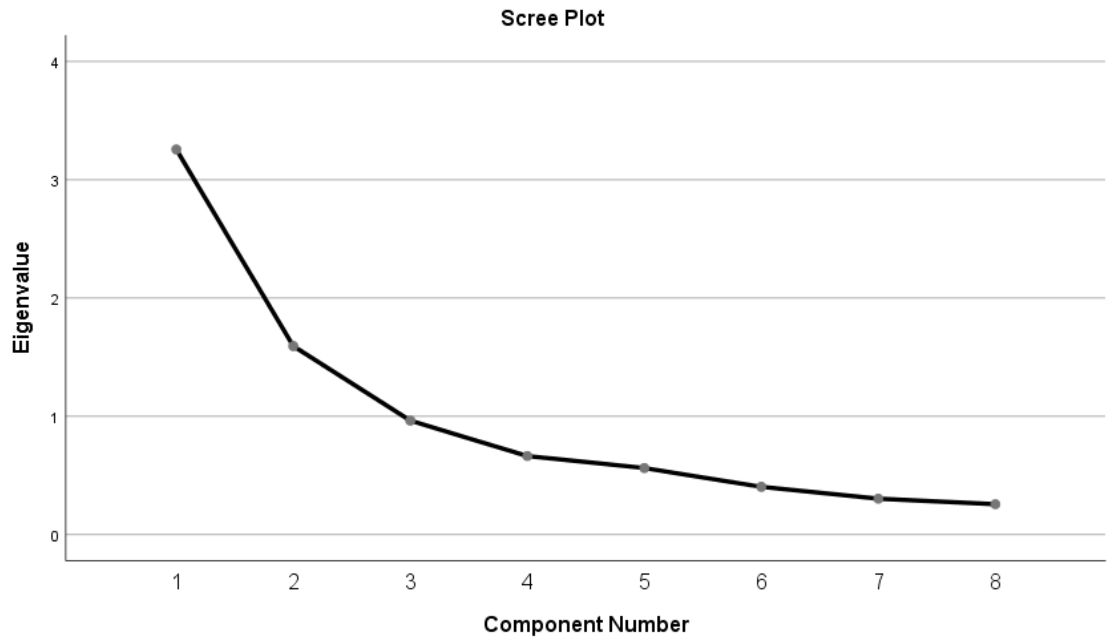


Management mechanisms enabling the adoption and implementation of gamified lean inventory management are represented by components 1 to 6. Although the eigenvalues of components 5 and 6 are below 1, they will be included in the scale reliability analysis to determine whether the impact on internal consistency, measured using Cronbach's alpha, is problematic. Components 5 and 6 will be removed if the Cronbach alpha value of the scale is below 0.7

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.827	.826	6

As shown above, the internal consistency of the scale measuring the mechanism of organisational management is internally consistent



Factor analysis is conducted again after removing the 6 components grouped into the single construct for the organisational management mechanisms enabling the adoption and implementation of gamified lean inventory management. Although the eigenvalues of component 4 is below 1, it will be included in the scale reliability analysis to determine whether the impact on internal consistency, measured using Cronbach's alpha, is problematic. Component 4 will be removed if the Cronbach alpha value of the scale is below 0.7

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.719	.719	4

The reliability of the remaining factors which are related to organisational infrastructure is shown below

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.784	.783	4

D.2 TESTS OF NORMALCY

The scales are tested for normalcy in order to ensure that the correct inferential statistical tests are applied. Normalcy is evaluated using the following criteria:

4. Skewness between -1 and 1 (Höllig et al., 2018)
5. Kurtosis between -1 and 1 (Höllig et al., 2018)
6. Shapiro-Wilk test of normality p-value < 0.05 (Das & Imon, 2016)

Descriptives

			Statistic	Std. Error
Lean inventory management score	Mean		17.21	.740
	95% Confidence Interval for Mean	Lower Bound	15.72	
		Upper Bound	18.71	
	5% Trimmed Mean		17.37	
	Median		18.00	
	Variance		23.002	
	Std. Deviation		4.796	
	Minimum		6	
	Maximum		25	
	Range		19	
	Interquartile Range		7	
	Skewness		-.511	.365

Descriptives

			Statistic	Std. Error
	Kurtosis		-.367	.717
Degree of gamification	Mean		.76	.166
	95% Confidence Interval for Mean	Lower Bound	.43	
		Upper Bound	1.10	
	5% Trimmed Mean		.65	
	Median		.00	
	Variance		1.161	
	Std. Deviation		1.078	
	Minimum		0	
	Maximum		4	
	Range		4	
	Interquartile Range		1	
	Skewness		1.362	.365
	Kurtosis		1.060	.717
What is the inventory performance of your organisation in days of inventory?	Mean		33.8571	4.36975
	95% Confidence Interval for Mean	Lower Bound	25.0322	
		Upper Bound	42.6820	
	5% Trimmed Mean		31.9365	
	Median		30.0000	
	Variance		801.979	
	Std. Deviation		28.31924	
	Minimum		2.00	
	Maximum		100.00	
	Range		98.00	
	Interquartile Range		43.00	
	Skewness		.909	.365
	Kurtosis		.014	.717
What is the annual revenue of your company in ZAR Millions?	Mean		73560.1090	19599.91594
	95% Confidence Interval for Mean	Lower Bound	33977.2757	
		Upper Bound	113142.9422	
	5% Trimmed Mean		57013.7692	
	Median		10500.0000	
	Variance		16134581608.550	
	Std. Deviation		127021.97294	
	Minimum		.00	
	Maximum		552000.00	
	Range		552000.00	
	Interquartile Range		52725.00	
	Skewness		2.164	.365

Descriptives

			Statistic	Std. Error
	Kurtosis		4.444	.717
Control barriers	Mean		2.8714	.10859
	95% Confidence Interval for Mean	Lower Bound	2.6521	
		Upper Bound	3.0907	
	5% Trimmed Mean		2.8624	
	Median		2.8000	
	Variance		.495	
	Std. Deviation		.70375	
	Minimum		1.40	
	Maximum		4.20	
	Range		2.80	
	Interquartile Range		1.20	
	Skewness		.288	.365
	Kurtosis		-.731	.717
Management barriers	Mean		3.0952	.11808
	95% Confidence Interval for Mean	Lower Bound	2.8568	
		Upper Bound	3.3337	
	5% Trimmed Mean		3.1270	
	Median		3.0000	
	Variance		.586	
	Std. Deviation		.76522	
	Minimum		1.00	
	Maximum		4.50	
	Range		3.50	
	Interquartile Range		1.00	
	Skewness		-.489	.365
	Kurtosis		.476	.717
Employee barriers	Mean		3.2321	.13100
	95% Confidence Interval for Mean	Lower Bound	2.9676	
		Upper Bound	3.4967	
	5% Trimmed Mean		3.2302	
	Median		3.5000	
	Variance		.721	
	Std. Deviation		.84895	
	Minimum		1.50	
	Maximum		5.00	
	Range		3.50	
	Interquartile Range		1.50	
	Skewness		-.222	.365

Descriptives

			Statistic	Std. Error
	Kurtosis		-.738	.717
Infrastructure barriers	Mean		3.0595	.13707
	95% Confidence Interval for Mean	Lower Bound	2.7827	
		Upper Bound	3.3363	
	5% Trimmed Mean		3.0853	
	Median		3.0000	
	Variance		.789	
	Std. Deviation		.88829	
	Minimum		1.00	
	Maximum		4.75	
	Range		3.75	
	Interquartile Range		1.31	
	Skewness		-.288	.365
	Kurtosis		-.259	.717

The Table above shows the descriptive results for the scale variables.

	Shapiro-Wilk		
	Statistic	df	Sig.
Lean inventory management score	.960	42	.149
Degree of gamification	.734	42	.000
What is the inventory performance of your organisation in days of inventory?	.887	42	.001
What is the annual revenue of your company in ZAR Millions?	.634	42	.000
Control barriers	.951	42	.072
Management barriers	.970	42	.321
Employee barriers	.946	42	.047
Infrastructure barriers	.970	42	.321

The Table above shows the Shapiro-Wilks test for normality. Based on the results of the skewness, kurtosis and Shapiro-Wilk statistic, the following variables are non-normal:

5. Degree of gamification
6. Inventory performance
7. Annual revenue
8. Employee barriers

Non-parametric statistical tests will need to be applied when evaluating hypothesis relating to the above 4 variables.

APPENDIX E: ETHICAL CLEARANCE

Graduate School of Business Administration
University of the Witwatersrand, Johannesburg

Wits Business School Ethics Committee
Constituted under the University Human Research Ethics Committee (Non-Medical)

Ethics Clearance Certificate

Ethics protocol number: WBS/BA0711892P/797

This certificate is only valid with a legitimate ethics protocol number and signed by the Researcher (below)

This certificate is only valid if accompanied by formal permission from the relevant stakeholder(s).

Project title	The gamification of inventory management in South African petrochemical refineries
Investigator / Researcher	Mr MELISIZWE MASHININI
Nature of Project	MM (Digital Business)
Decision of the Committee	Approved unconditionally
Issue Date of Certificate	2019/10/22
Expiry date	Date of submission of the project report
Chairperson	Prof Anthony Stacey ☎ +27 11 717 3587 +27 82 880 4531 anthony.stacey@wits.ac.za

Declaration by Researcher

One copy must be signed by the Researcher and returned to the Chairperson of the Wits Business School Ethics Committee.

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I undertake to resubmit the protocol to the Committee.

Signature

22 OCTOBER 2019
Date: