**The Impact of Thermal Ink Jet Printing within one selected Fast Moving Consumer Goods Organisation in SA: A Feasibility Study**

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**DECLARATION**

I declare that this research report is my own unaided work. It is being submitted to the Degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before any degree or examination to any other University.

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(Signature of Candidate)

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**ABSTRACT**

The primary objective of this research was to investigate the impact of thermal ink jet (TIJ) printing technology within a fast moving consumer goods organisation in SA, using Company 1 which consisted of 5 separate factories, as the selected organisation for the study. This was achieved by using the reliability, availability, maintainability and safety (RAMS) methodology as a basis in determining the current and future key performance indicators (KPIs) that were critical to the success of the organisation. Qualitative and quantitative research methods were used by allowing 15 employees at Company 1 to participate in an online survey, while a separate face-to-face interview was also conducted with a coding and marking supplier, known as Supplier 1. Based on the feedback received, it was discovered that the current printing technologies in use at Company 1 – which consisted of print-and apply, thermal transfer overprinting (TTO) and continuous ink jet (CIJ) technology – should include KPIs that measure label consumption, ribbon reel consumption, ink and solvent costs, line downtime, repairs and support costs, maintenance costs and working capital respectively. Furthermore, the KPIs that were most critical to measuring the success of future printing technologies, under the assumption that Company 1 invested entirely in TIJ technology, included ink cartridge costs, line downtime and operational efficiency. The second objective involved calculating the total cost of ownership (TCO) assuming Company 1 were to utilise TIJ technology at each of its 5 factories. The TCO results indicated that TIJ technology would prove to be a more cost effective printing technology in the long term on the corrugate, carton and horizontal-form-fill-and-seal flexible packaging format at every factory, due to the significantly reduced maintenance costs involved. The only exception was Factory 5's flexible packaging format, which predominantly utilised a vertical-form-fill-and-seal arrangement, which proved to be better suited to TTO technology.

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**CONTENTS**


| | | Page |
|---|---|---|
| DECLARATION | | ii |
| ABSTRACT | | iii |
| ACKNOWLEDGEMENTS | | iv |
| TABLE OF CONTENTS | | v – vii |
| LIST OF FIGURES | | viii – ix |
| LIST OF TABLES | | x – xi |
| NOMENCLATURE | | xii – xiii |
| **1** | **INTRODUCTION** | **1** |
| **1.1** | **Research Background** | **1** |
| **1.2** | **Context** | **2** |
| **1.3** | **Problem Statement** | **2 – 3** |
| **1.4** | **Critical Research Question** | **3** |
| **1.5** | **Objectives** | **3** |
| **1.6** | **Summary of Research Methods** | **3 – 4** |
| **1.7** | **Delimitations/Assumptions** | **4 – 5** |
| **1.8** | **Outline of Chapters** | **5 – 6** |
| **2** | **LITERATURE REVIEW** | **8** |
| **2.1** | **Conventional Printing** | **7 – 8** |
| **2.2** | **Digital Printing** | **8 – 10** |
| **2.3** | **Micromanufacturing Applications of Ink Jet Technology** | **10 – 11** |
| **2.4** | **Examples of Ink Jet in Micromanufacturing** | **11** |
| 2.4.1 | Chemical sensors | 11 |
| 2.4.2 | Delivery of drugs by implantable devices | 11 – 12 |
| 2.4.3 | Assembly and packaging | 12 |
| **2.5** | **Market Overview** | **13** |
| **2.6** | **Market Dynamics** | **13 – 14** |
| **2.7** | **Market Trends** | **14 – 15** |
| **2.8** | **Coding and Marking Challenges** | **15** |
| 2.8.1 | Electrospray | 15 – 16 |

| | | |
|---|---|---|
| 2.8.2 | Continuous ink jet (CIJ) | 16 – 17 |
| 2.8.3 | Thermal ink jet (TIJ) | 17 – 20 |
| 2.8.4 | Thermal transfer overprinting (TTO) | 20 – 23 |
| 2.8.5 | Micro piezo | 23 – 24 |
| 2.8.6 | Laser coding | 24 – 25 |
| **2.9** | **Printing Technologies Compared** | **25 – 27** |
| **2.10** | **Reliability, Availability, Maintainability and Safety (RAMS)** | **28 – 31** |
| **2.11** | **Conceptual Decision-making Framework** | **30 – 31** |
| **3** | **RESEARCH METHODS** | **32** |
| **3.1** | **Research Design** | **32 – 35** |
| **3.2** | **Sampling** | **35 – 36** |
| **3.3** | **The Survey** | **36 – 37** |
| **3.4** | **Validity and Reliability** | **38 – 39** |
| **4** | **ANALYSIS AND RESULTS** | **40** |
| **4.1** | **Objective 1** | **40 – 41** |
| **4.2** | **Objective 2** | **42 – 55** |
| **4.3** | **Objective 3** | **55 – 61** |
| **5** | **DISCUSSION** | **62** |
| **5.1** | **Evaluating the RAMS Framework** | **62 – 64** |
| **5.2** | **TCO Analysis** | **64 – 66** |
| **5.3** | **Survey Results** | **66** |
| **5.4** | **Validity and Reliability** | **67 – 68** |
| **6** | **CONCLUSIONS** | **69 – 71** |
| **7** | **RECOMMENDATIONS AND FUTURE RESEARCH** | **72 – 73** |
| **REFERENCES** | | **74 – 78** |
| **APPENDIX A** | **CORRUGATE TOTAL COST OF OWNERSHIP** | **79 – 86** |

| | | |
|---|---|---|
| **APPENDIX B** | **CARTON AND FLEXIBLES TOTAL COST OF OWNERSHIP** | **87 – 96** |
| **APPENDIX C** | **SURVEY MONKEY QUESTIONNAIRE** | **97 – 102** |
| **APPENDIX D** | **SURVEY MONKEY QUESTIONNAIRE ANALYSIS** | **103 – 128** |

**LIST OF FIGURES**


| Figure | Page |
|---|---|
| 2.1 Applications of ink jet technology have developed in 3 waves | 9 |
| 2.2 Classification of the most common ink jet printing technologies | 10 |
| 2.3 Top and side view of signal conditioning IC and flex circuit of disk drive | 12 |
| 2.4 Schematic diagram of electrospray deposition | 16 |
| 2.5 Thermal ink jet printer with a printing example on a bottle cap | 17 |
| 2.6 Example of photolithography on a TIJ printhead nozzle | 18 |
| 2.7 TIJ cartridge, printhead, photocell, cable and controller set-up | 19 |
| 2.8 TIJ printing in progress on carton packaging | 20 |
| 2.9 TTO integrated with a vertical-form-fill-and-seal packaging machine | 21 |
| 2.10 TTO in action | 22 |
| 2.11 Piezo printing on a corrugate tray holding tomato soup cans | 24 |
| 2.12 Laser coding applications on flexible reels | 25 |
| 4.1 Barcode information using print-and-apply technology applied to a corrugate | 42 |
| 4.2 Corrugate TIJ capex spend at Company 1 | 49 |
| 4.3 Corrugate NPV and IRR for Company | 50 |
| 4.4 Corrugate return on investment at Company 1 | 51 |
| 4.5 Corrugate annual operational saving | 51 |
| 4.6 Flexible wrap and carton TIJ capex spend at Company 1 | 52 |
| 4.7 Flexible wrap and carton NPV and IRR for Company 1 | 53 |
| 4.8 Flexible wrap and carton return on investment at Company 1 | 54 |
| 4.9 Flexible wrap and carton annual operational saving | 54 |
| D1 Number of respondents surveyed | 103 |
| D2 Department of survey respondents | 104 |
| D3 Coding technologies currently in use at Company 1 | 105 |
| D4 Reasons on why a BB and MD are required | 106 |
| D5 Feedback on the main packaging formats in use at Company 1 | 107 |
| D6 Associated risks in utilising TIJ technology | 108 |
| D7 Coding and marking technology best suited for Company 1 | 109 |
| D8 Time taken for the line operator to replace a TIJ ink cartridge | 109 |
| D9 KPIs that are most in measuring the performance of TIJ technology | 110 |
| D10 KPIs that are critical in measuring the performance of TTO technology | 111 |

D11 KPIs that are critical in measuring the performance of CIJ technology 112
D12 Reasons why TIJ printing will be a better alternative to current printing 113
D13 Potential impact on the supply chain at Company 1 115
D14 Potential impact on the operator at Company 1 116
D15 Recommended allocation of printing technologies for Company 1 117
D16 Coding and marking technologies with the highest capital cost 118
D17 Coding and marking technologies with the lowest capital cost 118
D18 Estimated annual opex cost of print-and-apply technology 119
D19 Estimated annual opex cost of current carton and flexible printing 120
D20 Average annual opex cost on current print-and-apply technology at Company 1 121
D21 Average annual opex cost on current TTO & CIJ technology at Company 1 121
D22 Most suitable printing technology from a RAMS perspective 122
D23 Integration capabilities between SAP and TIJ technology 123
D24 Largest risk to obtaining a readable barcode with TIJ technology 124
D25 Simplest way to save on consumable costs with TIJ printing 125
D26 Printing technologies that require replacement after 5 years 126
D27 Reasons why the technology requires replacement after 5 years 127
D28 Printing technologies that can operate beyond 5 years 127
D29 Reasons why the technology may operate longer than 5 years 128

**LIST OF TABLES**


| Table | Page |
|---|---|
| 2.1 Conventional printing technologies in use today | 8 |
| 2.2 Materials that have been deposited using ink jet technology | 10 |
| 2.3 Pros and cons of common printing technologies used in the FMCG industry | 26 |
| 2.4 Most appropriate printing technologies using RAMS | 30 |
| 2.5 Key RAM concepts to be considered as part of a printing technology solution | 31 |
| 3.1 Conceptual framework used to construct the online survey questionnaire | 37 |
| 4.1 Coding and marking KPIs based on RAMS methodology | 41 |
| 4.2 Capex and opex costs on TTO, CIJ, and TIJ technology | 43 |
| 4.3 Summary of participant survey results and Supplier 1's validation (part 1) | 57 |
| 4.4 Summary of participant survey results and Supplier 1's validation (part 2) | 58 |
| A1 Number of TIJ printers required for Company 1's corrugate packaging format | 79 |
| A2 Estimated TIJ cost per print for Company 1's corrugate packaging format | 79 |
| A3 Opex cost of current corrugated printing technology at Company 1 | 80 |
| A4 Capex costs of TIJ printing technology on Corrugates at Company 1 | 81 |
| A5 Opex costs of TIJ printing technology on Corrugates at Company 1 | 81 |
| A6 TCO analysis of Factory 1 using TIJ printing on corrugates | 82 |
| A7 TCO analysis of Factory 2 using TIJ printing on corrugates | 83 |
| A8 TCO analysis of Factory 3 using TIJ printing on corrugates | 84 |
| A9 TCO analysis of Factory 4 using TIJ printing on corrugates | 85 |
| A10 TCO analysis of Factory 5 using TIJ printing on corrugates | 86 |
| B1 Number of TIJ printers required for Company 1's flexible packaging | 87 |
| B2 Estimated TIJ cost per print for Company 1's flexible packaging format | 87 |
| B3 Capex costs of TIJ printing technology on flexibles at Company 1 | 88 |
| B4 Opex costs of TIJ printing technology on flexibles at Company 1 | 88 |
| B5 Number of TIJ printers required for Company 1's carton packaging format | 89 |
| B6 Estimated TIJ cost per print for Company 1's carton packaging format | 89 |
| B7 Carton capex costs of TIJ printing technology at Company 1 | 90 |
| B8 Carton opex costs of TIJ printing technology at Company 1 | 90 |
| B9 Opex cost of current flexible and carton printing technology at Company 1 | 91 |
| B10 TCO analysis of Factory 1 using TIJ printing on cartons and flexibles | 92 |
| B11 TCO analysis of Factory 2 using TIJ printing on cartons and flexibles | 93 |

B12 TCO analysis of Factory 3 using TIJ printing on cartons and flexibles 94

B13 TCO analysis of Factory 4 using TIJ printing on cartons and flexibles 95

B14 TCO analysis of Factory 4 using TIJ printing on cartons and flexibles 96

C1 Summary of the various coding and marking technologies used today 98

**NOMENCLATURE**

| | Abbreviation |
|---|---|
| Fast moving consumer goods | FMCG |
| South Africa | SA |
| Best before | BB |
| First-in, first-out | FIFO |
| Continuous ink jet | CIJ |
| Thermal transfer overprinting | TTO |
| Thermal ink jet | TIJ |
| Stock keeping unit | SKU |
| Quick response | QR |
| Total cost of ownership | TCO |
| Reliability, availability, maintainability, and safety | RAMS |
| Business intelligence | BI |
| Enterprise resource planning | ERP |
| Key performance indicators | KPIs |
| Drop-on-demand | DOD |
| Microelectromechanical system | MEMS |
| Integrated circuit | IC |
| Compound annual growth rate | CAGR |
| Research and development | R&D |
| Dots per inch | DPI |
| Mean time to failure | MTTF |
| Mean time between failures | MTBF |
| Failure mode and effect analysis | FMEA |
| Failure mode effect and criticality analysis | FMECA |
| Overall equipment effectiveness | OEE |
| Operational efficiency | OE |
| Operational utilisation | OU |
| Warehouse management system | WMS |
| Capital expenditure | CAPEX |
| Operatizing expenditure | OPEX |
| Consumer price index | CPI |

| | |
|---|---|
| Purchase order | PO |
| European article number | EAN |
| Original equipment manufacturer | OEM |
| Net present value | NPV |
| Internal rate of return | IRR |
| Return on investment | ROI |
| Rate of exchange | ROE |
| End of line | EOL |
| Earnings before interest and taxes | EBIT |
| Net operating profit after tax | NOPAT |
| Weighted average cost of capital | WACC |
| Year-on-year | YoY |
| Methyl ethyl ketone | MEK |
| Horizontal-form-fill-and-seal | HFFS |
| Vertical-form-fill-and seal | VFFS |
| Distribution centre | DC |

# CHAPTER 1 INTRODUCTION

## 1.1 Research Background

The fast moving consumer goods (FMCG) industry in South Africa (SA) is highly dependent on reliable and efficient, coding and marking technologies. The primary use of these printing technologies is for the marking of critical information onto packaging that is used to conceal all consumable goods (1). Such information includes the best before (BB) date, which is a compulsory requirement for the consumer purchasing the goods. Therefore, all perishable products, whether edible or not, require the products shelf life to be indicated on it by means of a best before (BB) date marking (2). This indicates when the product expires and needs to be disposed of, in order to avoid any potential harm to consumers (1,2).

The BB date is often accompanied by other information such as the manufacturing date, manufacturing time, barcodes, tracking numbers, etc. This information assists the FMCG organisation in determining the correct stock rotation practises based on first-in-first-out (FIFO) warehouse management processes. This ensures that the oldest stock is entering the retailer first, with the newer stock remaining within the respective distribution centres, or production facilities (1,2). Today there are various types of coding and marking technologies capable of delivering the necessary BB date information, however depending on several factors, some coding and marking technologies are more suitable than others.

In South Africa several of these coding and marking technologies exist, however, there is a prevalence in the use of continuous ink jet (CIJ) technology. The main reason for this is due to CIJ's capability of being applied onto any packaging substrate (3). Furthermore, the technology is readily available through most agents in the printing industry today, with support available 24/7. In addition to CIJ technology there are several other printing technologies in use today, both within the FMCG industry in SA and across FMCG organisations around the world (4). These additional coding and marking technologies include thermal transfer overprinting (TTO), thermal ink jet (TIJ) printing, laser printing, and lately micro piezo printing technology. While each technology has its place in every FMCG organisation, the ideal selection of printing technology depends on several critical success factors (3,4).

## 1.2 Context

Although TIJ printing technology does exist in the market today, the advantages and disadvantages of TIJ technology have not always been carefully considered against the current coding and marking technologies used within the FMCG industry today. These current technologies include TTO, CIJ, print-and-apply and to a lesser extent, laser marking and micro piezo technology (4). Consider an FMCG organisation in SA by the name of Company 1 which currently consists of 5 factories namely: Factory 1, Factory 2, Factory 3, Factory 4 and Factory 5 respectively. Each of these 5 Factories within Company 1 produce different stock keeping units (SKUs), however, all 5 Factories make use of the corrugate, carton, and flexible packaging formats. Furthermore, Factory 4 also makes use of the cans packaging format for some of its SKUs (3,4,5). While Company 1 currently utilises several printing technologies which include CIJ and TTO technology, there is currently no use of TIJ technology. Presently Company 1 uses print-and-apply technology for applying barcode prints onto labels, which are then applied onto corrugates. If, however, TIJ technology were to be adopted then the barcode print data could then be directly applied onto the corrugate packaging without the requirement for any labels. The TIJ printing application utilises technology that allows for ink dispersion (through a specialised heating process) to be extremely detailed without any ink disarray at the print head area. In addition to labels no longer being required, ink solvent requirements for cleaning any ink mess, also become redundant with TIJ technology. In addition to this, the ink consumption in Company 1 may be further reduced by integrating the 3 barcodes into 1 single barcode or quick response (QR) code that carries the same data as before but with a significantly reduced ink requirement (5,6).

## 1.3 Problem Statement

The implementation of TIJ printing would require that the technology be capable of delivering the same quality function as the current system, while simultaneously reducing the overall on-going maintenance and consumable costs of the current combined system at Company 1, which utilises CIJ and TTO at each of its 5 factories. The benefits of using TIJ printing could result in the utilisation of a standardised printing technology throughout Company 1, as well as, potentially a significant reduction in the overall total cost of ownership (TCO) of the entire printing application (7). This research thus proposes to investigate the impact of TIJ printing within a FMCG organisation in SA, using Company 1 as a case study (7).

### 1.4 Critical Research Question

What would be the impact of the implementation of TIJ technology in a selected FMCG company in SA?

### 1.5 Objectives

The primary objective of this research was to: Investigate the impact of the implementation of TIJ technology in a selected FMCG company in South Africa. This was achieved through the following research sub-objectives:

1. Determine the current and future printing technology key performance indicators (KPIs) which are critical to the success of the selected FMCG organisation, through the use of reliability, availability, maintainability, and safety (RAMS) as a basis.
2. Determine the respective financial benefits of TIJ printing using total cost of ownership (TCO) on the KPIs mentioned in 1.
3. Establish whether TIJ is a suitable printing technology for the selected FMCG company in South Africa.

### 1.6 Summary of Research Methods

Because of the combination of qualitative and quantitative research within the sub-objectives, a mixed-methods designs approach was adopted. KPI data for Company 1 were collected from current employees, at each of the 5 different factories. These KPIs were based on the critical success factors that measure the entire TCO of the printing application of current and future, coding and marking technologies (8). To gain an initial sample, 5 employees were interviewed from each of the 5 factories within Company 1. This equated to 25 employees from Company 1 in total. These employees included a combination of various staff that strategically, tactically, and operationally engage with the printing technology that is currently in use at Company 1. This included operators, team leaders, senior managers, and even site operation executives. Since these interviews were conducted in a non-face-to-face manner, an online survey tool such as Survey Monkey was used to assist with the survey distribution and interviewee feedback.

Furthermore, Survey Monkey allowed for the necessary analysis and illustration of data obtained from the interviewees (8). In addition to the interviews being conducted, annual spend data was collected on Company 1’s current printing technologies, based on the cost elements built into the assumptions made for the TCO analysis. This spend data was extracted via a business intelligence (BI) tool currently in use at Company 1 which tracked all spend, for every purchase order created and issued, with a respective goods receipt note. This effectively translated all spend that was captured into Company 1’s enterprise resource planning (ERP) system, particularly with regard to historical spend on the current printing technology suppliers. Once the necessary data were extracted, it was then filtered by factory, supplier, and printing technology. Hence, in addition to the qualitative data obtained from the non-face to-face interviews, there were also quantitative data obtained from Supplier 1’s face-to-face interview, as well as from the BI spend tool at Company 1 (8,9).

This combination of both qualitative and quantitative data analysis will form a basis for decision making on the most appropriate printing technology required at Company 1. Therefore an appropriate decision making framework that incorporates the TCO and RAMS methodology were constructed, to ensure the most suitable printing technology mix are proposed based on the requirements within Company 1 (8,9).
Ethics clearance number: MIAEC 014/18

### 1.7 Delimitations/Assumptions

- The research is restricted to one selected FMCG company known as Company 1, which consists of 5 Factories in Gauteng, South Africa.
- Company 1 has a general lack of operator skills on the factory floor, due to staff being contracted on a temporary basis, hence the ability to maintain the same operators for a prolonged period is significantly reduced.
- All 5 Factories at Company 1 utilise the following 3 main packaging formats namely – corrugates, cartons and flexible wraps.
- The printing supplier base within the Gauteng region is relatively small, in that there are currently only 2 suppliers capable of supporting and supplying each of the printing technologies conducted within this research.

- Common problems within Company 1’s print-and-apply label application, on the corrugate packaging format, have prompted the investigation into understanding if there may be a more suitable printing technology from a reliability, availability, maintainability and safety (RAMS) perspective while simultaneously delivering a reduced TCO.

## 1.8 Outline of Chapters

- Chapter 1 highlights the coding and marking industry in SA today, as well as the need and compulsory requirement for the BB date and manufacturing date, from a legislation perspective.

- Chapter 2 is a literature review that covers the advantages and disadvantages of the various coding and marking technologies currently in use, as each has its place in the printing industry today.

- Chapter 3 emphasises the specific research methods deployed from a qualitative and quantitative perspective, in order to determine the printing technology with the best TCO using Company 1, which contains 5 factories, as a case study. The methods used include the distribution of online questionnaires to employees at Company 1, in order to obtain their view on the most effective TCO printing solution. Furthermore, a TCO analysis was performed on the current printing solution at Company 1, and then also on the proposed TIJ implementation at Company 1, assuming the organisation were to transition entirely to TIJ technology. Lastly a face-to face interview was conducted with a coding and marking supplier (known as Supplier 1) that specialises in all printing technologies, in order to understand their view on the financial impact if an organisation such as Company 1 were to consider transitioning to TIJ technology.

- Chapter 4 is the analysis and results section which includes questionnaire feedback from Company 1 employees as well as the TCO and financial impact analysis of current and future printing technologies. This analysis is based on the assumption that Company 1 implements TIJ technology at all of its 5 factories. Furthermore, feedback from the face-to-face interview with Supplier 1 is also summarised along with their respective input on validity and reliability of the results.

- Chapter 5 is the discussion which decides on the most appropriate coding and marking set-up for Company 1, based on the analysis and results obtained, as well as on current research from the literature review.

- Chapter 6 is the conclusion and recommendations section which are obtained from the research done using Company 1 as a case study. Future recommendations for Company 1, as well as for other FMCG organisations, are also proposed.

## CHAPTER 2 LITERATURE REVIEW

The purpose of this literature review is to explain all coding and marking technologies which are currently available within the South African market. Furthermore the advantages and disadvantages of each are discussed, as each has their place in every fast moving consumer goods (FMCG) organisation. However depending on the requirements, constraints and criteria of the customer, some technologies are significantly more effective than others. This will be measured using key performance indicators (KPIs) that best define the total cost of ownership (TCO) of each technology as well as the most suitable technology from a reliability, availability, maintainability and safety (RAMS) perspective. The TCO is best defined as the initial capital outlay required to purchase the equipment, plus the on-going operating cost required to effectively utilise the equipment over its life-cycle. Coding and marking technologies that will be covered include continuous ink jet (CIJ), thermal ink jet (TIJ), thermal transfer overprinting (TTO), print-and-apply, micro piezo and laser coding.

### 2.1 Conventional Printing

Printing technology is one of the foremost inventions that fast-tracked the progress of humankind via the transmission, exchange and preservation of knowledge (10). Although Gutenberg's invention of the letterpress (10,11) with a movable lead type has been in existence for over 500 years, it has resulted in the past century as being the basis for graphic-arts reproduction. Together with the evolution of photography and the powerful combination of printing and computerised information technology, conventional printing technologies have further evolved, which have led to their widespread utilisation. Offset, gravure, flexographic and screen printing as shown in Table 2.1 are the major types of conventional printing technologies used today (10-12).

The basic principles of conventional printing (10,12) have remained the same for many years in that they all involve repetitive reproduction of the same image or text, multiple times. In most cases this is achieved by transferring liquid or semi-liquid ink from a particular master design to a substrate through direct contact. Any change to a printed product can only be done by changing the master design which involves making physical changes to the printing machine (10,12).

Table 2.1 Conventional printing technologies in use today (10)

| Printing Technology | Characteristics |
|---|---|
| Offset Printing (1) | - Printed pattern defined by differences in wetting of a plane surface<br>- Thin layers down to 0.5 µm are possible; high resolution (<20 µm)<br>- Dynamic viscosity of ink: 40 - 100 Pa.s (1) |
| Gravure Printing (1) | - Printed pattern defined by surface relief (recesses) of master<br>- Broad thickness range (~1 - 8 µm); high resolution (<20 µm)<br>- Dynamic viscosity of ink: 0.05 - 0.2 Pa.s (1) |
| Flexographic Printing (1) | - Printed pattern defined by surface relief (raised features) of master<br>- Thin layers of about 1 µm possible; high resolution (~20 µm)<br>- Dynamic viscosity of ink: 0.05 - 0.5 Pa.s (1) |
| Screen Printing (1) | - Printed pattern defined by openings in printing master<br>- Thick layers (>10 µm) possible; low resolution (~100 µm)<br>- Very broad dynamic viscosity range, from gravure inks to offset inks (1) |
| Ink Jet Printing (1) | - Master-less; droplet size determined by nozzle diameter and waveform<br>- Thin layers down to 100 nm possible; moderate resolution (~50 µm)<br>- Dynamic viscosity of ink: 1 - 20 mPa.s (1) |

## 2.2 Digital Printing

In contrast, the ink jet printer (12) which is now common in many households and offices today, works on a completely different principle to conventional printing technologies. Each droplet of ink which ranges from 10 – 100 µm in diameter, is formed under digital control, meaning that each print can be varied as and when required. Figure 2.1 describes the application of ink jet printing which can be described as being developed in three waves. The first wave indicates the concepts of ink jet printing which were first used in the 1970 and 1980s when products were being marked with dates and bar codes. The technology required for these purposes, which require high operating speeds, without the need for high resolution printing in the text, is now fully mature in utilising CIJ technology as a norm worldwide (10,12).

The next invention is shown in the second wave of Figure 2.1 which developed from the mid-1980s onwards and utilises drop-on-demand (DOD) printing (13) which is able to print much higher resolution than the early CIJ printers. Furthermore, DOD printing allowed for an increase in the capability of digital reproduction of text and images, at low costs, into households and small offices. The third wave which developed in the late 90s describes the use of ink jet printing as a manufacturing process. This advancement, which is coinciding with the use of ink jet for commercial printing, is still using the same basic principles of drop generation as the earlier applications, but now with an emphasis on reliability, accuracy, flexibility and robustness, which are critical in industrial applications. Ink jet printing is highly desirable for manufacturing due to several reasons (12-14). Firstly, it is a digital process meaning that the position of each dispersed ink droplet can be predetermined on a 2D grid. In addition to this, the ink droplet dispersion can also be changed in real-time, to adjust for distortion or misalignment of the substrate or to ensure that a certain height of the final deposit is achieved. Since it is a digital process, each product in a sequence, can simply be made different from every other. Since the pattern or text to be printed is now in a digital format, there may be large cost savings over conventional processes which require amendment of a physical mask (12-14).

Secondly, it is a non-contact technology with the only forces applied to the substrate being those of the impact from the ink droplets. Therefore, delicate substrates may be printed on which would not typically survive under more conventional printing methods. Ink may even be deposited onto rough substrates which are not even, provided the distance between substrate and printhead are at least 1mm. In conventional contact-based printing there may be instances of accidental contact of printed material being transferred to the substrate, which can lead to poor quality or contamination issues. Thirdly, a large variety of material may be used for print deposition. Through the selection of a robust printhead, liquids with viscosities ranging from 1 to 50 mPA s or higher can be printed. Lastly ink jet printing is modular and scalable. Multiple printheads can be arranged side-by-side to print in tandem, if a particular pattern requires a larger size, or the printheads can be placed one after the other to print different materials in sequence (12-14).

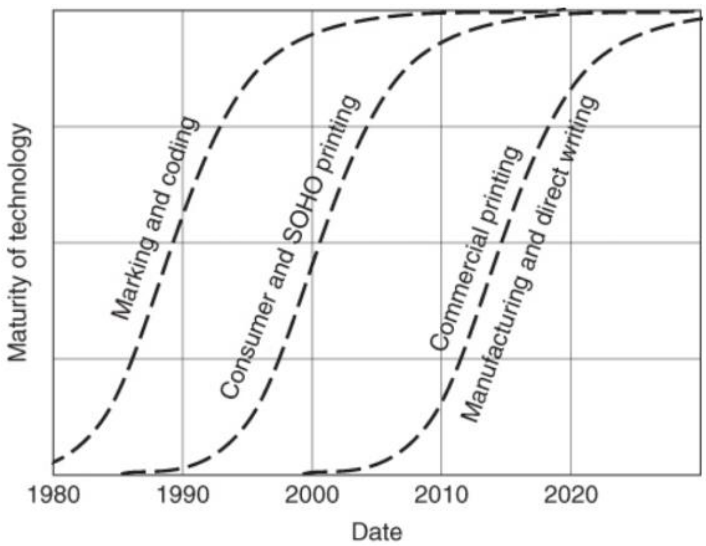


Figure 2.1 Applications of ink jet technology have developed in 3 waves (4)

Ink jet printing refers to the production of small drops of liquid and their deposition in specific locations on a substrate (13). Several methods of drop generation have been developed, as shown in Figure 2.2 which indicates 3 categories of ink jet technology. These include electrospray, CIJ or DOD technology. In addition, DOD technology may be further categorised into micro-piezo or TIJ technology (13,14).

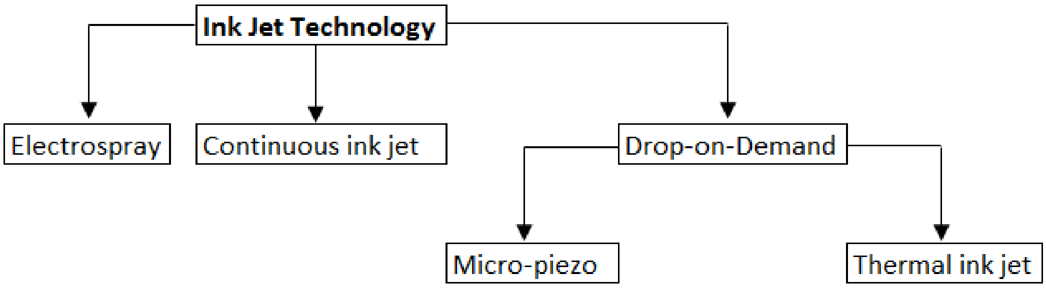


Figure 2.2 Classification of the most common ink jet printing technologies (13)

The diversity of fluids that have been dispensed through ink jet technology is also remarkable, given the fluid property restrictions of many materials. Inks alone represent a variety of materials. Dye and pigment aqueous dispersions (13) are the most commonly used in conventional printing. In addition volatile and low-volatility solvent inks are also in common use, as are UV-curing inks. Various material that have been dispensed through ink jet technology are shown in Table 2.2 (13,15).

Table 2.2 Materials that have been deposited using ink jet technology (13,15)

| Electronic/optical materials | Biological fluids | Organic solvents | Particle suspensions | Other |
|---|---|---|---|---|
| Liquid metals | DNA | Alcohols | Pigments | Sol-gels |
| Fluxes | Nucleic acids | Keytons | Cells | Thermosplastics |
| Photoresists | Amino acids | Aliphatics | Latex spheres | Thermosets |
| Epoxies | Cells | Aromatics | Metals | Acrylics |
| Polyimides | Proteins | Dipolar solvents | Teflon | Photographic developer |
| Elextroactive polymers | Lipids | | Phosphors | Fuels |
| Organometallics | Biosorbable polymers | | Ferrites | Aqueous adhesives |
| | | | Zeolyts | Odorants |

## 2.3 Micromanufacturing Applications of Ink Jet Technology

Ink jet printing technology has several attributes that can overcome the limitations of photolithographically based microfabrication methods (16). Since it is an additive method, material is only deposited where it is required. This allows for expensive material to therefore be saved. This allows for good saving from a TCO perspective particularly when the surface area to be deposited is small in comparison to the total area of the substrate. Furthermore, in addition to the low TCO as a result of low material usage, additive methods have little to zero waste, allowing for a more environmentally friendly process. In contrast, conventional printing (or subtractive methods) waste a significant amount of functional material (15). Another benefit is due to ink jet printing being a non-contact technology, meaning interaction between various materials when they are deposited, is significantly reduced. Fragile and sensitive surfaces can also be printed on due to the low inertial force applied by a deposited drop. Active deposition layers of different materials with different functions can be deposited onto without compromising their function, while also allowing for the creation of thick films by printing onto the same location multiple times. Since ink jet is a digital process, the cost and time associated with producing the masks required by photolithographically based microfabrication methods is eliminated. This results in a reduced TCO since the cost and turnaround time of fixed tooling is significantly reduced. Therefore the ability of ink jet to deposit onto individual dye and partial wafers, and to perform parametric process developments under digital control, can result in a significantly fast-tracked development time for a microfabricated device (15).

## 2.4 Examples of Ink Jet in Micromanufacturing

### 2.4.1 Chemical sensors

Chemical sensors represent a new area of research and development for microelectromechanical system (MEMS) devices (16) which has resulted from a demand for large volumes of low-cost sensors (17) for explosive, chemical warfare agents, drugs of abuse, industrial gases, residential gases, and many others. A large portion of these sensors utilise material that are electrically or photonically active, allowing for adhesion of material deposition and the sensor surface area. In most instances these surfaces are too delicate for photolithographic processing and hence typically utilise ink jet deposition in the last fabrication process (15-17).

### 2.4.2 Delivery of drugs by implantable devices

Drug delivery for diabetes, cancers, cardiac disease and neurological disorders is also on the increase (18) with the most commonly used implantable drug delivery device being the drug-eluding stent. This is used in order to keep coronary arteries open after an angioplasty operation (19). The sophisticated structure of a metal stent needs to allow for the device to contract in order to move along the blood vessel and then expand (or increase in diameter) and immobilise at the required location. In order to prevent tissue from growing over the stent and potentially obstructing the artery again, drugs are implanted into the stent. This is done by positioning the stent to allow for drugs to be placed on a specific side with a width of 50 – 150 µm. Several organisations are utilising ink jet technology for this process (15,18,19).

### 2.4.3 Assembly and packaging

Assembly of MEMS devices presents challenges that are different from and usually more difficult than those encountered in standard integrated circuit (IC) packaging. These challenges include the three-dimensionality of MEMS devices, fragile structures and hermetic sealing (20,21). An example of three-dimensional electrical interconnect is the assembly of signal conditioning IC to the flex circuit containing the read-write head for a hard disk drive. Figure 2.3 indicates the top and side view of an IC and flex circuit. The IC circuit has 80 µm electrical interconnect pads on the edge that interfaces with the flex circuit, which contains 60 µm traces. Solder has been deposited and partially reflowed into the corner formed by the IC, while micro piezo (DOD) ink jet technology is used to dispense droplets of the molten solder (15,20,21).

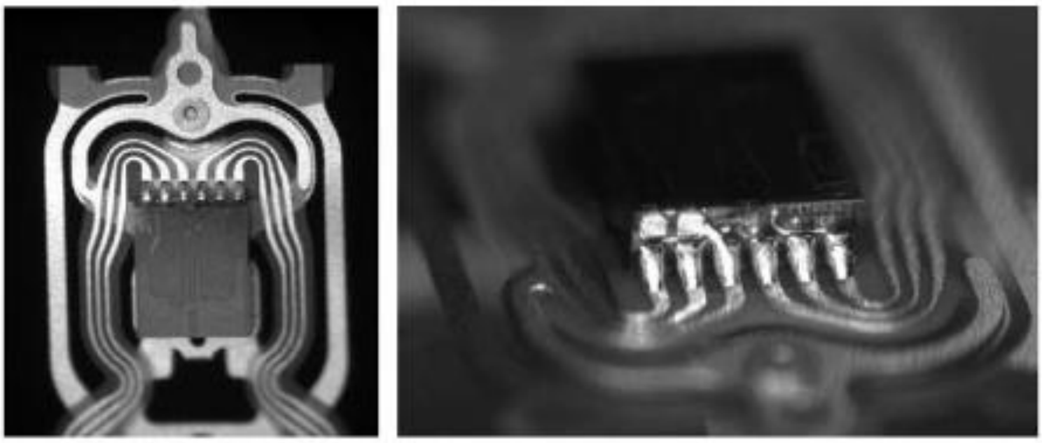

Figure 2.3 Top and side view of signal conditioning IC and flex circuit of disk drive (15)

## 2.5 Market Overview

Coding and marking systems provide the necessary product detail (22) on packaging such as the batch number, price, manufacturing and expiry date, and other related information to the end-user (22). The global coding and marking market covers smooth logistics processes where goods may be easily tracked from the manufacturing unit, to the retail outlets (22). Coding and marking play a critical role within the packaging and logistics industry for food and beverages, pharmaceuticals, chemicals, electronics and other major industries (2,22).

## 2.6 Market Dynamics

The global coding and marking market is expected to witness a compound annual growth rate (CAGR) of 9.4%, during the forecast period, to reach $5310.5 million by 2023. Coding and marking for the food and beverage industry is expected to dominate the market during the forecast period (2). Continuous ink jet (CIJ) has been the largest contributor to the market and is expected to grow at the largest CAGR during the forecast period. Asia-Pacific and Europe together contributed over 70% in the global coding and marking market in 2016, as a result of increased demand within the food and beverage industry, pharmaceutical, and cosmetic industries. These industries capture the major market due to high demand at the customer's end (2). A change in lifestyle is impacting the buying behaviour of customers (23) as trends such as rising sales of packaged food, bottled water, fruit juice, and milk drink have increased demand on the global packaging environment and hence also the coding and marking market (2,3,23).

Furthermore, the pharmaceutical packaging industry has also shown recent increased sales due to the higher demand for blister packaging and equipment technological advancements. Such advancements in technology within coding and marking equipment are also driving the coding and marking market (22). Asia-Pacific is expected to significantly contribute to growth in the coding and marking industry as a result of stricter government regulation for coding and marking in the packaging industry worldwide, due to an increase in demand for packaging foods and beverages in countries such as China and India (2,23). Therefore the most advanced packaging lines should be deployed while also performing the coding and marking process. The batch and code number along with the manufacturing date should be printed on the outer packaging. This practice is strictly followed in the food and beverage industry (2), pharmaceutical industry (2), and the labelling of agricultural products (2). The adherence to coding and marking regulation on these industries is likely to drive the market in the future (2,22,23).

## 2.7 Market Trends

A rise in imports and exports of coding and marking machines worldwide due to globalisation within the packaging industry has benefited all stakeholders within the entire supply chain (24). Major players are migrating their manufacturing bases to various countries (24) in order to expand their global presence. Globalisation has made possible the exchange of advanced coding technologies, from one country to another, resulting in growth within the coding and marking industry (25). Furthermore major players are investing in emerging markets such as Brazil, India and China due to the growing demand of packaged food and beverages in these regions. In addition, green technology marking and coding is a current major trend in the market (2).

Various patents have been developed for biodegradable resin-based marking devices. The use of green printing technology and techniques is being used to reduce the impact on the environment (24). Recently there has also been significant investment in research and development (R&D) with the global coding and marking market by major players to increase performance and output. These major players include Danaher Corporation, Hitachi Industrial Equipment Systems Co. Ltd., Illinois Tool Works Inc., and Domino Printing Sciences. R&D efforts have largely been focused on increasing the robustness of the ink consumed and technical advancements in coding and marking equipment (2).

The largest obstacles within the market is currently the increase in the price of raw materials. These raw materials typically account for more than 50% of the total cost of the packaging. Examples include polypropylene, polyethylene, resin and polyester, paper, aluminium foil, and ink prices which are mainly driven by supply and demand, that is constantly changing (2). In these market conditions supply can easily change with the global economy, weather conditions, and several other factors. Increases in the price of raw materials will ultimately affect the operating costs and hence the profit of the organisation utilising these technologies. Currently the coding and marking industry is dominated by tier 1 and tier 2 suppliers internationally (2). The tier 1 suppliers include

Danaher Corporation, ID Technology LLC, Ink jet Inc., Hitachi Industrial Equipment Systems Co. Ltd., Illinois Tool Works Inc., Domino Printing Sciences plc. and Dover Corporation. The tier 2 supplier include smaller scale suppliers that have observed a niche in particular technologies such as TIJ technology, rather than focusing on common technologies that the tier 1 suppliers use. Recently this has resulted in the tier 1 suppliers opting to enter into joint venture, or merger and acquisition, with the tier 2 suppliers in order to expand on their portfolio size as well as increase their global presence to meet demand requirements of the future (2).

## 2.8 Coding and Marking Challenges

### 2.8.1 Electrospray

Drops and jets of liquid can be drawn from liquid surfaces in the presence of electric fields (14). This was first analysed by G.I. Taylor in 1964 with the raised cone often referred to as the Taylor cone (14) as shown in Figure 2.4. This method which is known as electrospray can produce drops and jets much smaller than the nozzle from which they eject, however producing drops of a well-managed size using electrospray is difficult to achieve (12). Various modes of operation are used depending on the geometry, materials and electric field. The liquid can be ejected in a succession of relatively large drops, or at higher field strengths, as a continuous ink which can break up into a continuous drops which as they are electrically charged, will repel each other and diverge into a cone (12,14).

A variant of this technique has been developed by Tonejet. The printhead structure has no nozzles but instead an array of points or needles which sit just below the surface of the recirculating ink well and form an electrode. The ink comprises of charged pigment particles dispersed in a non-polar solvent. An electric field between the points and another electrode, separate from the ink, causes the charged particles to be ejected. The concentration of particles is significantly higher in the ejected drops when compared to the bulk ink (12,14).

Electrospray technology currently lags behind CIJ and DOD technology since the running costs required are significantly higher than that of micro-piezo or TIJ technology. Furthermore electrospray technology is still under development and hence, is not as mature as either micro-piezo or TIJ in its evolution (12,14).

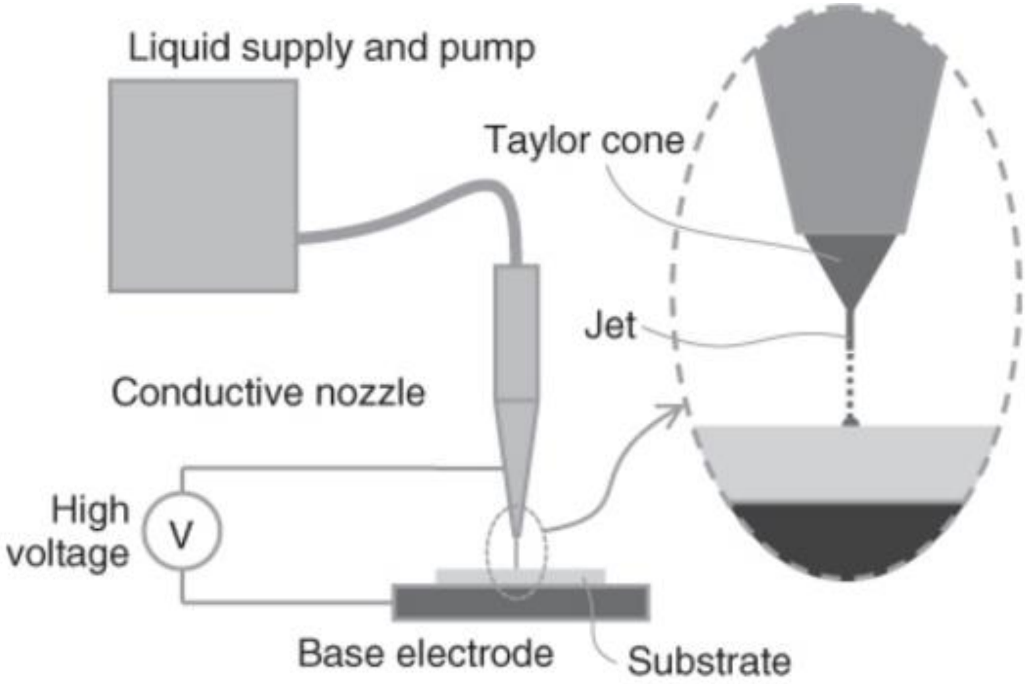


Figure 2.4 Schematic diagram of electrospray deposition (14)

### 2.8.2 Continuous ink jet (CIJ)

In CIJ technology, a high pressure pump pushes ink from a reservoir through a gunbody and a microscopic nozzle, resulting in a continuous flow of ink particles. Figure 2.5 is a typical example of a CIJ printing unit, as well as an example of its print capability on a metal cap. With CIJ technology a piezoelectric crystal creates an acoustic wave which vibrates within the gunbody, resulting in a stream of liquid dispersing into droplets at a high frequency (3,5,6,10,12,13).

These ink droplets are exposed to an electrostatic field created by a charging electrode as they develop. This causes each droplet to have a controlled varying electrostatic charge. The charged droplets travel through an electrostatic field and are refracted via electrostatic deflection to print on the required substrate, or to continue on a collection bucket for re-use. Only a small portion of the ink droplets are actually used to print, with the larger remaining ink droplets being recycled (3,5,6,10,12,13).


Figure 2.5 Thermal ink jet printer with a printing example on a bottle cap (3)

CIJ technology is one longest ink jet technologies still in use today (13,14). This is due to several benefits which include extremely high velocity of the ink droplets, allowing for significant distance between the printhead and the surface onto which it is printing, as well as high drop ejection frequency which allows for high line speed printing. Furthermore, since the nozzle jet is constantly printing, there is minimal opportunity for clogging, allowing for volatile solvents like ketones and alcohols to be used. This results in the ink immediately adhering to the surface onto which it is being printed with rapid drying. The ink system does require on-going regulation of the solvents, in order to combat solvent evaporation during nozzle ejection and gutter recycling from the venting process (3,13,14).

### 2.8.3 Thermal ink jet (TIJ)

Thermal ink jet is a technology that was developed by Hewlett Packard in the 1970s as an alternative technology to dot matrix printing (13,14). It offers a very high print quality with ink contained in a cartridge that does not make any contact onto the surface which it is printing. In the TIJ process, a cartridge is used which contains a series of tiny chambers with each containing a heater, as shown in Figure 2.6 which makes use of photolithography. In order to eject an ink droplet from each firing chamber, a pulse of current is passed through the heating resistor in rapid condensation of the ink inside the chamber to form a bubble, which causes a large pressure increase, forcing a droplet of ink through the printhead nozzle and onto the surface which it is printing (3,5-7).

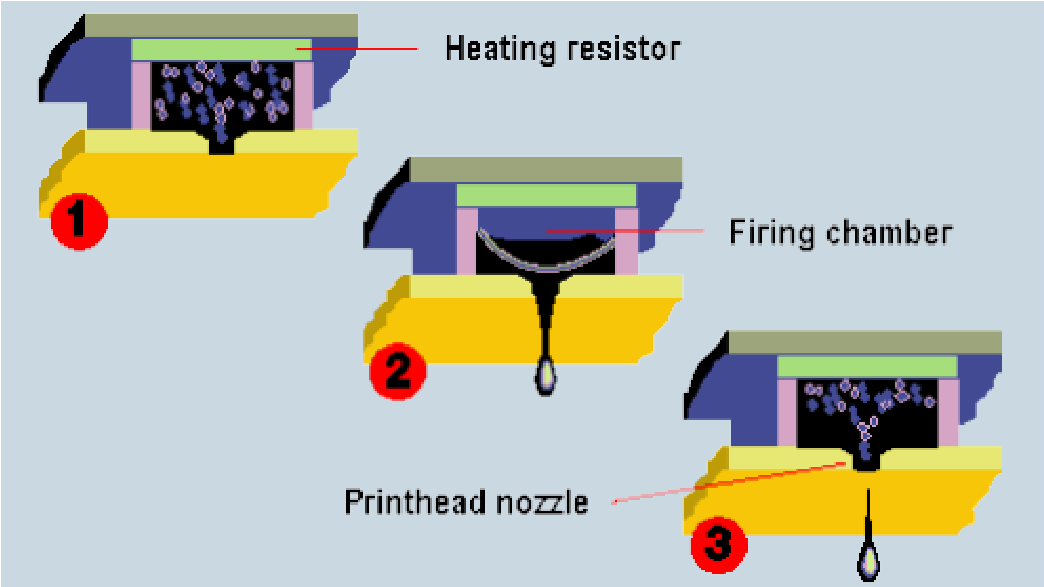


Figure 2.6 Example of photolithography on a TIJ printhead nozzle (6)

Inks utilised are typically water-based and use either pigments or dyes as the colourant. These inks require a volatile component to form the required vapour bubble, or else droplet ejection will not occur. Once the thermal heater cools the vacant ink channels are then refilled with filtered ink and this cycle can repeat up to 6900 times per second. Since no unique material requirements are necessary, the printhead is often cheaper than other ink jet based systems. Figure 2.7 shows a typical TIJ set-up that includes a modular design with no moving parts or easy points of failure. The cartridge is inserted into the printhead, while a photocell completes the set-up between the printhead and cartridge, which in turn are connected to a controller via a cable (3,5-7).

Replaceable ink cartridges are used to produce prints with detail measured from 300 to 600 dots per inch (DPI), however print speed is significantly affected by an increased DPI in prints. Each cartridge contains 2 columns of 150 nozzles offset by half a pitch from each other. When both nozzles are ejecting ink at the correct time, the result is a print up to ½" long, which contains 300 dots, resulting in an effective resolution of up to 600 DPI. Horizontal resolution may be varied up to 600 DPI to give a maximum of 600 x 600 DPI. Ink economy may be increased by varying the font style, size and resolution used. Print speed varies with TIJ technology depending on the horizontal resolution of the print, but even at the lowest resolution speeds of up to 220m/min may be obtained. Typical examples of where TIJ technology is best suited include – 2D, datamatrix, and bar codes at high speeds on packaging such as cartons and blister - both of which are common within the pharmaceutical industry (2,3,5-7).


Figure 2.7 TIJ cartridge, printhead, photocell, cable and controller set-up (6)

TIJ was initially developed for printing onto paper-based, porous surfaces (13) as the inks used water as the main solvent, however the technology has expanded into using alcohol as the main solvent and hence being entirely capable of printing onto a wide range of materials including non-porous materials such as blister foils, varnished cartons as shown in Figure 2.8 and flexible film (26). There are several advantages to using TIJ technology but these are best defined using the fours C's which include:

- Cleanliness – no ink spillage or dangerous ketones present.
- Convenience – once activated with a cartridge installed, printing commences immediately.
- Cost – competitive on both capital and consumable costs with negligible maintenance.
- Clarity – print resolution may be adjusted up to 600 x 600 DPI with different inks to suit a range of printing surfaces.


Figure 2.8 TIJ printing in progress on carton packaging (6)

### 2.8.4 Thermal transfer overprinting (TTO)

TTO is a digital process in which material is applied to a substrate by melting a coating of ribbon to mark onto the substrate onto which it is being applied (27). It differs to TIJ printing since it does not make use of an ink cartridge but instead utilises a ribbon for printing applications. Furthermore, TTO is a digital printing technology that overcomes many of the deficiencies of analogue printing solutions such as hot stamp/hot foil and roller coders (27). In TTO the material requiring the print and the ribbon both travel beneath the printhead, and come into contact, resulting in a wax-based ink from the ribbon melting onto the material being marked. Once ventilated the wax adheres to the material (5,6,28).

TTO uses a thermal printhead and a thermal transfer ribbon. The printhead comprises a ceramic coating, covering a row of thermal pixels at a resolution of 12 printing dots per mm allowing for high resolution codes. The print information transfers to the thermal printhead and the individual printing dots are heated as required. The ink within the ribbon is transferred onto the printing material in the specified target area to produce a code (7). TTO systems were developed to specifically mark on flexible film and labels. Figure 2.9 indicates typical examples of where TTO should be used for flexible printing applications (28). TTO was designed as an advancement over traditional analog coding technologies such as hot stamp and roller coding. TTO utilises digital printing technology on flexible films especially those used within the food and beverage industry (28).

TTO is a contact technology since it comes into direct contact with the flexible film or label onto which it is printing. To cater for this requirement TTO printers are typically installed directly onto the packaging machine or labelling system, and usually very close to the point of packaging. TTO Ribbon has a very thin layer of dried ink on one side of a polyester film and a suitable lubricant on the other side. The ink layer is a mix of either wax and resin, or just resin. The use of a wax/resin mix is mostly on general purpose applications whereas a resin only ribbon may be used in specific applications where there may be an environmental impact such as extreme heat or where wax adhesion becomes a challenge from a chemical resistance perspective. Therefore the ribbon requirement type depends on the application and well as the exact coding requirements (28).

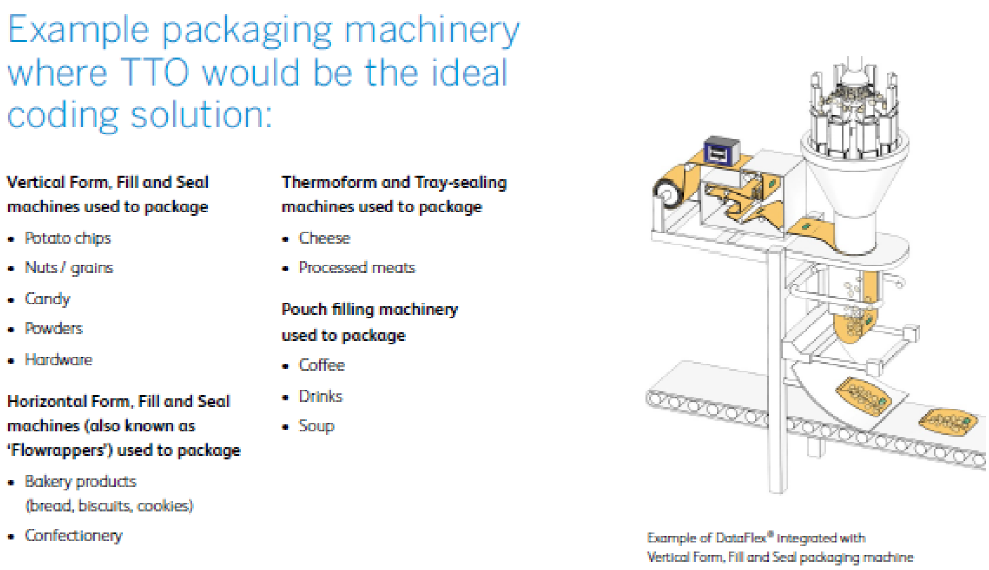


Figure 2.9 TTO integrated with a vertical-form-fill-and-seal packaging machine (28)

Their reason for a change from analog to digital technologies was due to the constant change in customer and regulatory requirements within the supply chain, with analog technologies being limited in terms of flexibility as they are constrained by the number of characters held in the type of holder, or the amount of text that may be added to perimeter of the respective die wheel. TTO is not limited in this manner as more code content can be easily added without any of the mechanical changes to the printer itself as shown in Figure 2.10. Furthermore as different SKUs are introduced, TTO offers a simple way to change coding and marking from one SKU to the next (28).

Print jobs are saved via the print controller and may also be recalled within seconds. Another advantage that TTO offers offer hot-stamp technology is that is does not require a warm up period to start printing. Once powered on TTO can start printing in under 60 seconds while hot-stamp requires a warm-up period to bring the holder to the necessary temperature needed to start printing. TTO therefore manages to bring more flexibility and productivity to the flexible film packaging lines (5,6,28).

Figure 2.10 TTO in action (28)

TTO printers are programmable and capable of generating variable data for each print. The high resolution print head has the capability of printing text, graphics, batch numbers, real-time dates, as well as barcodes. The latest TTO technology also significantly improves on ribbon consumption by leaving a 0.5mm gap between each print making TTO a highly economical solution for flexible film applications. Furthermore TTO also allows for the user to plan line downtime by knowing the number of codes achieved per ribbon reel, and hence allowing for the user to therefore accurately calculate the number of intervals required for ribbon reel changeovers. The cassette design also allows for a fast change of ribbon reels, resulting in a reduced impact on the operational utilisation (OU) of the line. Furthermore, TTO may be used for intermittent or continuous printing, however print resolution is maxed out at 300 DPI. The printhead is a solid ceramic block without any sharp edge to ensure that no slitting of flexible film occurs when printing. Since the technology is digital there is no need to stop the machine if new codes or print data are required, as this updates in real-time (28).

Analog coding technology such as hot stamps and roller coders, utilise metal stamps that are held in a heated block. These stamps require replacement every time a new job is required in order to amend the code data. Reliability of analog technology is also significantly worse than digital as the stamps reduce their imprint capability over time with heavy use, resulting in faded and poor quality prints, which increase the requirement for waste and rework. Digital technology improves line uptime by eliminating human error in instances where an operator may insert an incorrect code or make a spelling mistakes. This is because digital technology contains a real-time clock computer chip which has basic computing ability capable of determining the 'best before' date automatically from date of manufacture (5,6,28).

This is not the case with analog technology since fixed stamps are used and hence there is no ability to code in real-time. TTO consumables include ribbon reels (of up 1200m) which can be changed quickly with ease and guidance from software control parameters on ribbon tension and movement. Analog printing technology requires a much longer time than TTO to replace a ribbon, as often there in no ribbon cassette so the operator needs to gain entry inside the packaging machine to replace the ribbon. Furthermore updating data and changing stamps requires cooling down of the coder and then warming up again causing greater line downtime than TTO technology (28).

### 2.8.5 Micro piezo

In micro piezo technology a permanent print head is used. Today several commercial and industrial ink jet printers utilise piezoelectric material in an ink filled chamber behind each respective nozzle, instead of a heating element. As shown in Figure 2.11 when a voltage is applied, the piezoelectric material changes shape, resulting in a change in structure of the piezoelectric material, which initiates a pressure pulse in the fluid causing ejection of a droplet of ink from the nozzle. Piezoelectric permits for a broader range of inks in comparison to TIJ as there is no requirement for a volatile component and no build-up of ink residue, however the printhead is more expensive than TIJ technology, as a result of the utilisation of piezoelectric material. Furthermore, the cartridge life is significantly improved when compared to TIJ technology (3).


Figure 2.11 Piezo printing on a corrugate tray holding tomato soup cans (3)

The micro piezo technology process makes use of software to apply between 0 to 8 drops of ink per dot only where required. The advantages of micro piezo technology include high speed, long service life, and a space between the print head and the substrate onto which it is printing, as well as a low operating cost (3).

### 2.8.6 Laser coding

Laser marking is done by using a laser system to engrave or vapourise the surface of a material, thus leaving a permanent engraved mark. These coders are capable of marking text, graphics, and variable data on many types of substrates including plastics, glass, paper, and cartons. Figure 2.12 indicates a laser marking set-up on a flexible reel application. Since no ink or solutions are used, laser coding technology is environmentally friendly and cost effective (3).

Figure 2.12 Laser coding applications on flexible reels (3)

The technology uses a focused beam of light that is deflected via mirrors which are controlled using a galvanometer assemblies. The galvanometer technology enables laser coding and marking onto moving or static products, at varying speeds. Laser technology permanently changes the coating from the surface onto which it is marking. For instance, when laser is applied to painted substrate, the very top layers of the paint are permanently removed, and when marking onto plastics there is a chemical change in the nature of the plastic resulting in a permanent mark or change in the colour of the paint. When marking on glass the laser indents micro cracks that also leave a permanent mark without compromising the strength of the material (3).

## 2.9 Printing Technologies Compared

The advantages and disadvantages of each printing technology need to be weighed up against each other in order of importance when a particular FMCG organisation decides upon the appropriate mix of printing technologies. Furthermore, several factors need to be considered depending on the packaging substrate being printed on. Ideally, these factors should then be built into a model that assesses the TCO with several scenarios depicting the main printing technologies used (4,7). A summary of the pros and cons of the most prevalent printing technologies used in the FMCG industry is shown in Table 2.3.

Table 2.3 Pros and cons of common printing technologies used in the FMCG industry (3,7,25,26,28)

| Printing Technology | Pros | Cons |
|---|---|---|
| CIJ | 1. Solvent based MEK inks which dries immediately on porous and non-porous surfaces with good adhesion<br>2. Inexpensive capital costs<br>3. Cheap consumable costs | 1. Print quality is low, therefore it is difficult to obtain class barcodes and 2D codes<br>2. High TCO<br>Solvent based MEK inks result in health and environmental issues<br>3. Low reliability |
| TTO | 1. Less prone to issues of static charge which affect ink adhesion<br>2. High throughput<br>3. Green technology | 1. Only can be used on flexible material<br>2. Contact is required with the substrate<br>3. Dust and particles permanently damage the print heads<br>4. Ribbon reel changes are time consuming |
| TIJ | 1. Prints may be adjusted into higher resolutions of up to 600dpi<br>2. The technology is maintenance free<br>3. Printing components do not consist of any moving mechanical parts<br>4. Solvent and water based ink types allow for marking on any substrate<br>5. Integration capabilities (SAP, remote VPN support,BI monitoring, etc.)<br>6. Low TCO<br>7. Green technology | 1. Cartridges need to be replaced when ink is low<br>2. Slightly less ink adhesion than TTO on flexible applications<br>3. Static charge may be encountered on flexible applications<br>4. Capping may occur if printers stand for extended periods |
| Laser | 1. High print quality<br>2. Non-contact printing resulting in less wear and tear<br>3. High throughput | 1. High capital costs<br>2. Health and safety issues need to be carefully considered<br>3. Limited lifespan of laser<br>4. Substrate surface need to be carefully considered |

Today CIJ is one of the most widely used printing technologies due to its inexpensive capital costs, its ability to adhere to any substrate, and its low consumable costs. The disadvantages with CIJ technology, however, include among others, the on-going maintenance cost which is often difficult to quantify in monetary terms (7,26). Typically a FMCG organisation may decide to quantify this value by calculating the impact of the particular manufacturing lines downtime as a result of CIJ printer downtime. This then involves calculating number of SKUs that have not been produced based on the manufacturing lines overall equipment effectiveness (OEE), as well as the finished goods service level impact (if any). The problem with this approach is that in many instances the service level impact can only be identified at a later stage depending on the sales outcome. Furthermore, some CIJ inks also contain hazardous substances such as methyl ethyl ketones (MEK) which can be harmful to humans and the environment depending on the quantities in which they are used (4,6,25).

Although TTO technology may only be applied to flexible packaging (or labels), it does provide better adhesion than both TIJ and CIJ technology, especially when applied on a vertical-form-fill-and-seal (VFFS) bagger packaging line. Another benefit is that TTO does not experience any print issues with electrostatic charge build up, which is a common phenomenon experienced on flexible type packaging during printing. From a consumables perspective, TTO technology requires a ribbon reel change, rather than an ink cartridge change which is used with CIJ and TIJ technology. The downside of TTO is that these ribbon reel changes can also be time consuming which may impact on a manufacturing lines operational efficiency (OE). In addition, with TIJ technology a single cartridge replacement results in a brand new print head, whereas with TTO technology a ribbon reel replacement does not. Therefore any print head trauma experienced as result of on-going contact, may also result in degradation of print quality over time, unless the entire print head is replaced on a TTO printer. This may easily be encountered in dusty environments where dust particles clog the print head nozzles resulting in permanent damage to the print head, hence affecting the overall print quality (7,26,28).

Similar to CIJ printing, TIJ may also print on any packaging substrate with the only difference being the type of inks used, which shall be either solvent based or water based inks respectively. In addition to print substrate flexibility, TIJ technology requires significantly less maintenance than both CIJ and TTO technology. The only significant operating cost is the consumable cost of the ink cartridges (5). This cost may potentially be further reduced with good procurement practice which may include the purchasing of larger ink cartridge quantities that result in reduced pricing from the supplier (4-7,25,28). Further total cost of ownership (TCO) efforts can then also include an investigation into the consumption of ink via the unique business intelligence (BI) integration capability of TIJ technology. This can be analysed along with the necessary FMCG's enterprise resource planning (ERP) data. Opportunities from thereon, may include lowering the print DPI to acceptable levels that still achieve the required scanability and legibility, yet utilise significantly less ink. Another benefit with TIJ technology, is that OE and operational utilisation (OU) of the packaging lines may also be significantly improved due to the low maintenance requirements and fast replacement times of ink cartridges which typically takes only a few seconds if new cartridges are nearby (4,7,26,28). A cartridge change is also a straight forward process to execute, with minimal training required.

Thus, these aspects need to be considered as key requirements from a reliability (29), availability (29), maintainability (29) and safety (RAMS) (29) aspect for the proposed selection of printing technologies at Company 1. Combining the RAMS requirements together with the most feasible TCO that delivers the greatest return on investment (ROI), should result in the most suitable printing technology selection for Company 1.

### 2.10 Reliability, Availability, Maintainability and Safety (RAMS)

With the RAMS methodology (30) and the associated tools and techniques used, an organisation can easily determine the most suitable printing technology based on its current needs (31-34). An organisations reputation is closely linked to the reliability of its products. The more reliable a product is, the more likely the organisation is to have a good reputation. While a reliable product may not radically affect customer satisfaction in a positive manner, an unreliable product will certainly attract customer dissatisfaction (30). Therefore high reliability is an essential requirement for customer satisfaction**.** In instances where a product is unable to perform its intended function within the warranty period, the replacement or repair costs will not only reduce profits, but also empathise negative attention. A constant effort toward improved reliability shows existing customers that a manufacturer is serious about its product, and committed to customer satisfaction. This behaviour ensures a positive impact on the future business of the manufacturer and also provides them with a competitive edge (31-34).

Several organisations use reliability data and combine it with other cost information to illustrate the cost-effectiveness of their products. This life-cycle cost analysis can indicate that although the initial cost of the product may be higher than those of the competitor's product, the overall lifetime cost (30) or total cost of ownership (TCO) are lower than that of the competitors because their product requires fewer repairs or less maintenance. Demand from the customer for an effective reliability program is continuously increasing based on the advantages of such programmes. Many organisations now publish a products reliability number to increase competitiveness (7,26,31-34) .

Reliability is the probability that parts, components, products, or systems will perform their designed-for functions without failure in specified environments for desired periods, at a given confidence level (35). Today more and more products are being advertised by their reliability ratings, such as their failure rate, mean time between failures (MTBF), and reliability (35-39). This ensures competition. The MTBF refers to the sum or average time between 2 successive components failures. MTBF is usually applied to a group of similar equipment, such as all coding and marking technologies in a factory (35-39). With respect to the reliability of components, mean life of a part or component refers to the average life of a specified number of components which is measured over their entire lifecycle.

The mean time to failure (MTTF) refers to the sum of the survival time (up time) for all components put under test divided by the number of components, which are failed. Therefore a reliable printing technology from a MTBF and MTTF would therefore be TIJ technology as well as TTO depending on the required application. This is due to the low maintenance requirement for both technologies when used on the appropriate substrates (32-34,42,43). As shown in Table 2.4 there are several reasons why reliability is an essential attribute of a product as not only do the MTTF and MTBF play a significant role in the reliability of a product, but so do the associated risks that the product poses in instances whereby there is failure to perform accordingly (31-34,36-43).

Availability is another measure of performance that integrates both reliability and maintainability parameters and depends on the number of failures that occur and how quickly faults are rectified (32). The up time is the actual time the product is available for use while the denominator indicates total time for which the product is required to function. The down time is the sum of all delays such as repairs, maintenance, etc. (31,36-41). The availability perspective can be analysed using the failure mode and effects analysis (FMEA) scoring system (32) to determine the severity and critical failure points of the technologies being selected. Due to the maintenance requirements being significantly lower with TIJ and TTO technology when used on the correct substrates, it becomes noticeable that risk is also substantially reduced (3-7,25,28,32-34,42,43).

Maintainability can be defined as the probability that failed equipment is restored to operable condition in a specified time (32) (called ‘downtime’) when maintenance is performed under stated conditions. It characterises the flexibility of the product to the recognition and elimination of failures as well as their prevention. The 2 most important factors that decide the worth of a product are reliability and maintainability (32). Therefore the greater the reliability and maintainability of a product, the shorter it’s downtime and the rarer it fails (31,32,36-41). Similarly from a maintenance perspective the most suitable technologies are again TIJ and TTO technology, provided they are both used on the correct substrates. Redundancy also plays an important role, as often the technologies share a modular design that allows for the interchanging of critical parts and components when needed. Furthermore, by applying the 80/20 Pareto principle (9) it may be observed that consumables (such as ink cartridges for TIJ technology and ribbon reels for TTO technology) may in many instances be the largest cause of downtime (3,4,25,5-7,28,32-34,42,43).

Safety is often divided into 3 categories that are related to 3 main assets namely persons, equipment and the environment (32). Safety is a state where the risk has been reduced to a level that is as low as reasonably practicable and where the remaining risk is generally accepted (32). Failure modes and effects analysis (FMEA) (9) is a safety and reliability assessment technique to assess all potential failure modes and their failure effects of the components comprising a system, which may affect the entire system performance. It also identifies how to avoid the failure modes and how to reduce the impacts of the failure modes (33). The FMEA technique can be expanded upon further to determine the failure mode effect and criticality analysis (FMECA), which is used to determine the safety implication when deploying TIJ and TTO technology. With reduced maintenance requirements, modular design and reduced MTTF and MTBF it can be shown that the risk of hazards is minimal. Furthermore, both technologies offer a safe user-friendly experience for the operator with no (potentially) harmful MEK solvents, which is sometimes found in CIJ technology (4,6,25,32-34,42,43).

Table 2.4 Most appropriate printing technologies using RAMS (32-34,42,43)

| RAMS | Tools & Techniques | Most Suited Technologies | Comments |
|---|---|---|---|
| Reliability | - MTBF<br>- MTTF | TIJ / TTO<br>TIJ | - Low maintenance and higher uptime<br>- Low maintenance and higher uptime |
| Maintainability | - Redundancy<br>- Pareto distribution | TIJ<br>TIJ / TTO | - Standard interchangeable parts<br>- Consumable issues result in the biggest downtime i.e. cartridge and ribbon reel shortages, failures, etc. |
| Availability | - FMEA | TIJ /TTO | - Probability and severity of failure is low |
| Safety | - FMECA | TIJ /TTO | - Probability and severity of failure and hazard is low |

### 2.11 Conceptual Decision-making Framework

A conceptual decision-making framework was then developed (as shown in Table 2.5) by combining the RAMS and TCO methodologies for each of the printing technologies considered. This includes CIJ, TIJ, TTO, print-and-apply, micro piezo and laser coding technology. The main requirements for each dimension of the RAMS framework were listed, in order for Company 1 to make a printing technology selection that best meets each of these requirements. Once a combination of printing technologies is selected, the financial feasibility of the proposed printing technologies may then be calculated through a detailed TCO analysis. This will involve calculating the net present value (NPV) (30), internal rate of return (IRR) (30) and return on investment (ROI) (30) at each of the 5 Factories within Company 1. In order to add further robustness to the printing selection process, a comprehensive analysis may also be done to determine the key performance indicators (KPIs) that are most critical to measuring the performance of each printing technology. This may be established by utilising the RAMS methodology in collaboration with the findings from the literature review. This will result in KPIs being created for each printing technology across the 4 RAMS dimensions namely – reliability, availability, maintainability and safety (32). This combination of – RAMS requirements, TCO and KPIs – will allow for a systematic approach to determining the best selection of printing technologies at Company 1.

Furthermore, a roll-out plan for each of the 5 Factories can be determined, based on the TCO results of the Factories that deliver the greatest financial benefits first. The TCO analysis however, will complement the RAMS framework to provide the best printing selection possible. Lastly, since this research is being conducted on a FMCG organisation within Gauteng, which utilises common packaging formats to several other FMCG organisations, it is expected that a similar printing technology selection and rollout-plan applies to these other organisations too.

Table 2.5 Key RAM concepts to be considered as part of a printing technology solution

| **Conceptual Framework** | | | |
|---|---|---|---|
| **RAMS and TCO Methodology Applied to CIJ/TIJ/TTO/Print-and-Apply/Micro Piezo/Laser Coding Technologies** | | | |
| **Reliability** | **Availability** | **Maintainability** | **Safety** |
| - Mean time between failures (MTBF) | - Downtime | - Consumables required | - Working environment |
| - Mean time to failure (MTTF) | - Working capital | - Operational efficiency | - Hazardous inks |
| - Overall equipment effectiveness (OEE) | - Supplier support | - Contact or non-contact technology | - User-friendly |
| - Digital vs conventional printing | - Operational efficiency | - Complexity of equipment | - Best before as a requirement |
| - Print quality (DPI) | - Operational utilisation | - Spare part requirements | |
| - Printing substrate<br>* kraft board corrugates<br>* kraft or klafold board cartons<br>* BOPP flexible film | - Failure mode and effect analysis (FMEA) | - Capex cost (capex)<br>- Operating cost (opex) | - Batch management<br>- Failure mode effects and criticality analysis (FMECA) |

# CHAPTER 3 RESEARCH METHODS

There are two main approaches to a research problem namely, qualitative research and quantitative research. Qualitative research is primarily exploratory research which is used to gain an understanding of both verbal and nonverbal data. It provides insights into the problem or assists in developing ideas and hypotheses for potential quantitative research. Qualitative research can be used to uncover trends in both verbal and nonverbal data allowing for a deeper understanding of the research at hand. Qualitative data collection methods vary using loosely structured or non-standardised observations and interviews, from a typically small and selected sample size (8).

Quantitative research is used to quantify the problem by way of analysing numerical data using statistical analysis. It is used to quantify known variables and generalise the results using a large sample size. Quantitative research uses measureable data to formulate facts and uncover patterns in research. Quantitative data collection methods are more structured than qualitative data collection methods and include the use of standardised instruments (8).

## 3.1 Research Design

Research design must be driven by the critical research question, the research objective and its sub-objectives. Some objectives and sub-objectives call for only quantitative research, while some call for only qualitative research, while others are best addressed using mixed-methods designs which utilises both kinds of research. There are several reasons why it is sometimes best to adopt a mixed-methods designs approach which includes (8):

1. Completeness – the research question can now be fully addressed by collecting, analysing and interpreting quantitative and qualitative data.
2. Complementarity – quantitative aspects of the study can compensate for weaknesses in qualitative research, and vice versa.
3. Hypothesis generation and testing – qualitative data often provides information that assists in the formation of hypotheses relating to cause-and-effect relationships, which as a result can be tested using quantitative research.

4. Development of appropriate research tools and strategies – one type of data can inform and assist in the subsequent collection of another type of data. For example, unstructured interviews that provide qualitative data can be used to guide the construction of appropriate questions for a survey that can provide quantitative data.
5. Resolution of puzzling findings – In a quantitative study, various results may on occasionally appear inconsistent or contradictory. Qualitative data may provide further insight by assisting with explanations that make sense of the data.
6. Triangulation – this allows the research to provide a more convincing case for certain conclusions if both qualitative and quantitative data lead to those conclusions.

The primary objective of this research was to: Investigate the impact of the implementation of thermal ink jet (TIJ) technology in a selected fast moving consumer goods (FMCG) organisation in South Africa. This was achieved through the following research sub-objectives, using Company 1 as the selected company:

1. Determine the current and future printing technology key performance indicators (KPIs) which are critical to the success of the selected FMCG organisation through the use of reliability, availability, maintainability, and safety (RAMS) as a basis.
2. Determine the respective financial benefits of thermal ink jet (TIJ) printing using total cost of ownership (TCO) on the KPIs mentioned in 1.
3. Establish whether TIJ is a suitable printing technology for the selected FMCG company in SA.

Based on these sub-objectives, a mixed-methods designs was adopted as both quantitative and qualitative methods were combined into the study, particularly from sub-objectives 2 and 3 respectively. Furthermore, a multiphase iterative design approach was used since there were 3 sub-objectives, with sub-objective 1 providing foundational data onto which the second and third sub-objectives could expand (8). The design is iterative, since research was back and forth between qualitative and quantitative methods, thus allowing each new body of data to develop the conceptualisation and implementation of subsequent phases. In other words, breaking down the 3 sub-objectives into a series of actionable steps resulted in the following, with steps 3a and 3b being two complementary parts of a single data-collection step (8):

1. Collect qualitative research data regarding the most important KPIs used by FMCG organisations, based on the RAMS methodology.
2. Collect quantitative data on Company 1’s existing opex spend, based on the current coding and marking technologies currently in use.

3a. Obtain capex and opex quotes from existing printing technology suppliers at Company 1.

3b. Obtain capex and opex quotes from a printing technology supplier known as Supplier 1, assuming Company 1 were to implement TIJ technology throughout the organisation.

4. Determine the financial benefit of TIJ printing using total cost of ownership analysis (TCO).
5. Conduct qualitative surveys for staff at Company 1 to determine their views on the most suitable printing technology for Company 1.
6. Make modifications to the qualitative survey in point 5 and improve the questions, for purposes of conducting a qualitative interview with Supplier 1, to determine their view on the most suitable printing technology for Company 1.
7. Determine - in collaboration with steps 4, 5 and 6 – the most suitable printing technology for Company 1.
8. If necessary, repeat steps 6 and 7 through additional iterations.

By moving back and fourth between these 8 steps, the 3 main sub-objectives can be achieved. Sub-objective 1 includes steps 1 – 2 above. Using the RAMS methodology as a basis, the most suitable printing technology for use at Company 1 was identified. This was determined utilising the various tools and techniques featured within the RAMS framework, that can best assist in implementing the most suitable KPIs that will measure the success the of selected printing technologies to be deployed at each respective Factory within Company 1. Once the respective KPIs have been identified the top 2 KPIs from each aspect of the RAMS methodology will be summarised. The pros and cons of each technology will be carefully considered against the requirements of Company 1’s needs. Furthermore each technology will be summarised with the leading KPIs from a

RAMS perspective in order to provide a suitable basis for sub-objective 2. Sub-objective 2 includes steps 3a – 4 which was to obtain the capex and opex quotes from Company 1's existing printing technology suppliers. This forms a baseline for the TCO calculation that will be done for Factories 1 – 5 within Company 1. Furthermore, Supplier 1 also provided a quote on the capex and opex costs for Factories 1 – 5, under the assumption that Company 1 were to implement TIJ technology throughout the organisation.

In order to determine the TCO of TIJ printing, it becomes critical that all proposed capex and opex costs, at each factory within Company 1 are taken into consideration for Company 1 to make an informed decision, from a cost and cash flow perspective. The TCO calculation therefore needs to include a comparison of what Company 1's current printing opex requirement would be, versus the proposed opex requirement of TIJ technology. This involves calculating the proposed printing technologies net present value (NPV), internal rate of return (IRR) and return on investment (ROI), for each packaging format, at each factory within Company 1 (7,26,44,45). Once the TCO calculation is done a roll-out plan will be recommended in order to determine the order in which the 5 Factories at Company 1 should migrate to TIJ technology. Furthermore, any Factories with a negative NPV, IRR or ROI will likely be considered to migrate last, or alternatively remain on their current printing technology.

### 3.2 Sampling

Sub-objective 3 includes steps 5 – 8, whereby nonprobability sampling called purposive sampling was used. This involved selecting a chosen sample of 5 employees from each of the key departments within Company 1. These key departments included, operations, research and development (R&D), supply chain, logistics, information technology (IT), engineering, marketing, projects, finance, manufacturing, quality, and head-office. Purposive sampling is when people are specifically chosen, as the name implies, for a particular purpose. In this case the desired sample chosen required junior to senior level employees, at each key department. The reason for this was to obtain a diverse input of participants that strategically, tactically, and operationally engage with the printing technology in use at Company 1, while also limiting bias to any specific department (8). The selected sample therefore included a mix of buyers, as well as mid to senior managers. The survey was sent to 5 employees at each of the 12 departments, which equated to 60 employees in total, however, only 15 employees responded to the online survey. While only a 25% response rate occurred, this was sufficient for purposes of analysis from a qualitative perspective. Distribution and employee feedback to the online survey was done using an online survey tool, known as Survey Monkey, which also allowed for the necessary analysis of data obtained from the interviewees (8,28,46).

Prior to commencing with the online survey all participants were also given instructions on the survey (as shown in Appendix C) as well as a summary of the various characteristics of each printing technology, as shown in Table C1, to assist them with completing the survey. The reason for this was that although all of the participants had already been previously exposed to the current and proposed coding and marking technologies, some may have forgotten the names, characteristics and features of each technology.

### 3.3 The Survey

The survey consisted of a total of 29 questions as shown in Appendix C. Questions 1 – 5 were to form a baseline to determine the department and potential factory that each participant worked in. Questions 6 – 8 were to ensure that the participants understood the application of coding and marking onto the main packaging formats used at Company 1. Questions 9 – 11 were designed to obtain confirmation from participants on what they felt were the most suitable KPIs based on the RAMS methodology from the literature review, for each of the printing technologies in use today. Questions 12 – 15 were designed to verify if the participants understood the proposed benefits of TIJ technology over the current technologies in use at Company 1. Questions 16 – 29 were designed to check if the participants correctly understood the concept of TCO, by understanding the benefits that TIJ technology has over the other technologies currently in use at Company 1.

A conceptual framework was developed from the literature review (refer to Table 2.5 in chapter 2) and combining this with the RAMS and TCO methodologies, across all major printing technologies currently in use in SA today. The survey questions (shown in Appendix C) were developed using this framework as tabulated in Table 3.1.

Table 3.1 Conceptual framework used to construct the online survey questionnaire

<table>
<tr><th colspan="8">Conceptual Framework</th></tr>
<tr><th colspan="8">RAMS and TCO Methodology Applied to CIJ/TIJ/TTO/Print-and-Apply/Micro Piezo/Laser Coding Technologies</th></tr>
<tr><th colspan="2">Reliability</th><th colspan="2">Availability</th><th colspan="2">Maintainability</th><th colspan="2">Safety</th></tr>
<tr><td>Mean time between failures (MTBF)</td><td rowspan="5">Question 12<br>Question 14</td><td>Downtime/maintenance</td><td>Question 6<br>Question 23</td><td>Consumables required</td><td>Question 8<br>Question 9<br>Question 25</td><td>Working environment</td><td>Question 26<br>Question 27</td></tr>
<tr><td>Mean time to failure (MTTF)</td><td>Working capital</td><td rowspan="4">Question 9<br>Question 10<br>Question 11</td><td>Operational efficiency</td><td>Question 9</td><td>Hazardous inks</td><td>Question 6</td></tr>
<tr><td>Overall equipment effectiveness (OEE)</td><td>Supplier support</td><td>Contact or non-contact technology</td><td>Question 29</td><td>User-friendly</td><td>Question 14</td></tr>
<tr><td rowspan="2">Digital vs conventional printing techniques</td><td>Operational efficiency (OE)</td><td>Complexity of equipment</td><td>Question 14<br>Question 23<br>Question 27</td><td>Best before as a requirement</td><td rowspan="2">Question 4</td></tr>
<tr><td>Operational utilisation (OU)</td><td>Spare part requirements</td><td>Question 9</td><td>Batch management (FIFO, etc.)</td></tr>
<tr><td>Print quality (DPI)</td><td>Question 6<br>Question 12<br>Question 13</td><td rowspan="2">Failure mode and effect analysis (FMEA)</td><td rowspan="2">Question 12<br>Question 27<br>Question 29</td><td>Capex cost</td><td>Question 16<br>Question 17<br>Question 26<br>Question 28</td><td rowspan="2">Failure mode effects and criticality analysis (FMECA)</td><td rowspan="2">Question 12<br>Question 27<br>Question 29</td></tr>
<tr><td>Printing substrate<br>- kraft board corrugates<br>- kraft or klafold board cartons<br>- BOPP flexible film</td><td>Question 5<br>Question 7<br>Question 12<br>Question 13<br>Question 15</td><td>Operating cost</td><td>Question 6<br>Question 8<br>Question 18<br>Question 19<br>Question 20<br>Question 21</td></tr>
</table>

### 3.4 Validity and Reliability

In order to determine the validity and reliability of the results obtained from the online survey and from the RAMS and TCO analysis, Supplier 1 will be presented with the online survey results in order to determine if these required further analysis, or if they make sense based on known theory behind each technology. Furthermore, Supplier 1 had the capability of providing and supporting any of the technologies analysed to Company 1. Therefore, a summary of the online survey results from questions 6 – 29 were tabulated for Supplier 1 to simply agree or disagree on.

Supplier 1 will also then provide further feedback on results to questions which they disagreed on. Supplier 1 is a coding and marking supplier capable of providing any of the necessary printing technologies currently available in the market today. Supplier 1 had been previously approached by Company 1 due to failure of the print-and-apply applicators that were currently applying printed barcode label stickers onto the corrugates at each of the 5 Factories. The basis of Supplier 1’s analysis will be in terms of the RAMS methodology, the KPIs required to measure each printing technology, and the TCO of each technology, which were all previously determined from the literature review and online survey. Supplier 1’s feedback will then be analysed based on their experience within the coding and marking industry in SA. Aside from providing a solution with the lowest TCO analysis, Supplier 1’s actual industry experience with previous organisations was recorded, in order to determine the validity and reasoning on why TIJ technology has not seen substantial penetration over existing technologies currently in use within the FMCG industry in SA today.

Furthermore, for purposes of reliability and validation of the TCO analysis, the capex and opex costs of the current printing technology in use at Company 1 (which is CIJ and TTO technology) will be vetted against the capex and opex costs of using TIJ technology throughout Company 1. Based on theory from the literature review, TIJ technology should indicate a lower TCO when compared to the current printing technologies in use at Company 1. This is analysed in terms of the 3 main packaging formats currently in use at Compay 1, which includes the corrugate, carton and flexible packaging formats. The flexible packaging format, however does have two types of packaging lines at Company 1. For example, Factories 1 – 4 utilise the horizontal-form-fill-and-seal (HFFS) flow wrapper packaging lines and these lines should indicate a lower TCO using TIJ technology, rather than TTO technology. Factory 5, however, utilises vertical-form-fill-and-seal (VFFS) bagger packaging lines which should indicate a lower TCO using TTO technology, rather than TIJ technology.

# CHAPTER 4 ANALYSIS AND RESULTS

In this chapter feedback will be presented on all 3 research objectives. This includes determining the current and future printing technology KPIs which are critical to the success of a fast moving consumer goods (FMCG) organisation through the use of reliability, availability, maintainability, and safety (RAMS) as a basis. Furthermore a summary of the financial benefits through the use of total cost of ownership (TCO) analysis will be summarised and illustrated for each factory, assuming Company 1 were to adopt TIJ technology throughout the organisation. Lastly, the most suitable printing technology will be established based on both, the TCO analysis performed, as well as feedback obtained from the participant questionnaire and supplier interview.

## 4.1 Objective 1

As shown in Table 4.1, from a reliability perspective it can be shown that the most critical KPIs are line downtime and overall equipment effectiveness (OEE). This is primarily due to the mean time to failure (MTTF) and the mean time between failures (MTBF) measurements which are 2 critical measures used to assess the reliability aspect of each of the main printing technologies considered. MTTF and MTBF are therefore represented with the KPIs of line downtime (expressed in minutes) and OEE (expressed as a percentage) respectively. Operational efficiency (OE) and operational utilisation (OU) are the most suitable KPIs to measure the availability of each printing technology. OE is represented as a percentage and is a ratio of the output gained over the input required to run the machine in monetary terms. Furthermore, working capital is also considered as a critical KPI to every printing technology, with the exception of thermal ink jet (TIJ) technology. The reason for this is due to each printing technology requiring spare back-up printers due to the likelihood of failure. Continuous ink jet (CIJ), thermal transfer overprinting (TTO), print-and-apply, and micro piezo technology are all contact technologies that require contact to be made with the substrate onto which they are printing. Only laser and TIJ technology are contactless technologies, however, laser like CIJ, TTO, print-and-apply, and micro piezo all contain pneumatic components that degrade over time. For this reason working capital (or spare units) is not a KPI for TIJ technology only, due to the low maintenance requirement.

The consumable cost for each technology are one of the two KPIs that effectively measure the maintenance of each printing technology, expressed in rands. This is effectively the ink solvent cost, ribbon reel cost, label cost, ink cartridge cost, and water based ethyl acetate and ethanol inks costs for CIJ, TTO, print-and-apply, TIJ and micro piezo technology respectively. The second most critical KPI is the maintenance cost, which are often repair and support costs that are charged through printing supplier. TIJ technology only considers its consumable cost which is the ink cartridge that requires replacement once empty. Maintenance is considered negligible for TIJ technology, based on the literature from Chapter 2. Lastly is safety, which is of concern to CIJ and laser technology only. CIJ utilises inks with harmful solvents such as methyl-ethyl-ketones that can be toxic over prolonged periods, while laser technology requires a significantly ventilated area to ensure there is no overheating or risk of fire.

Table 4.1 Coding and marking KPIs based on RAMS methodology (43)

| **Printing Technology** | **Reliability** | **Availability** | **Maintainability** | **Safety** |
|---|---|---|---|---|
| CIJ | - Line downtime<br>- OEE | - OE<br>- OU<br>- Working capital | - Ink solvent costs<br>- Maintenance costs | - Hazardous ink solvent usage |
| TTO | - Line downtime<br>- OEE | - OE<br>- OU<br>- Working capital | - Ribbon reel costs<br>- Maintenance costs | - None |
| Print-and-apply | - Line downtime<br>- OEE | - OE<br>- OU<br>- Working capital | - Label costs<br>- Maintenance costs | - None |
| TIJ | - Line downtime<br>- OEE | - OE<br>- OU | - Ink cartridge costs | - None |
| Laser | - Line downtime<br>- OEE | - OE<br>- OU<br>- Working capital | - No consumables<br>- Maintenance costs | - Ventilation level |
| Micro piezo | - Line downtime<br>- OEE | - OE<br>- OU<br>- Working capital | - Water based ethyl acetate<br>- Propanol and ethanol inks | - None |

## 4.2 Objective 2

Depending on the printing technology used several assumptions may be made with respect to the annual total cost of ownership (TCO). For example a summary is shown in Table 4.2 indicating the annual costs that need to be taken into consideration for the 3 printing technologies used (7). ‘Yes’ indicates an annual cost to be considered while ‘No’ indicates there is no annual cost, or no significant annual cost to be considered. Printhead and installation costs are required for all 3 printing technologies as part of the initial capital outlay, however the operating costs vary significantly amongst the 3 printing technologies being considered for purposes of TCO. For instance, print technician costs need to be taken into account for TTO applications used on the labels for corrugate packaging (which is referred to as print-and-apply technology), but not for CIJ and TIJ printing technologies (28). Figure 4.1 indicates a label already applied to a corrugate box using print-and-apply technology. Print technician costs would typically involve a FMCG organisation recruiting technicians from the respective print-and-apply supplier in order to provide 24/7 on-site support at the FMCG organisation. The technician is usually stationed at the point of label application onto the corrugate packaging, in order to ensure a label is always applied to each corrugate SKU with minimal downtime (3,7,28).

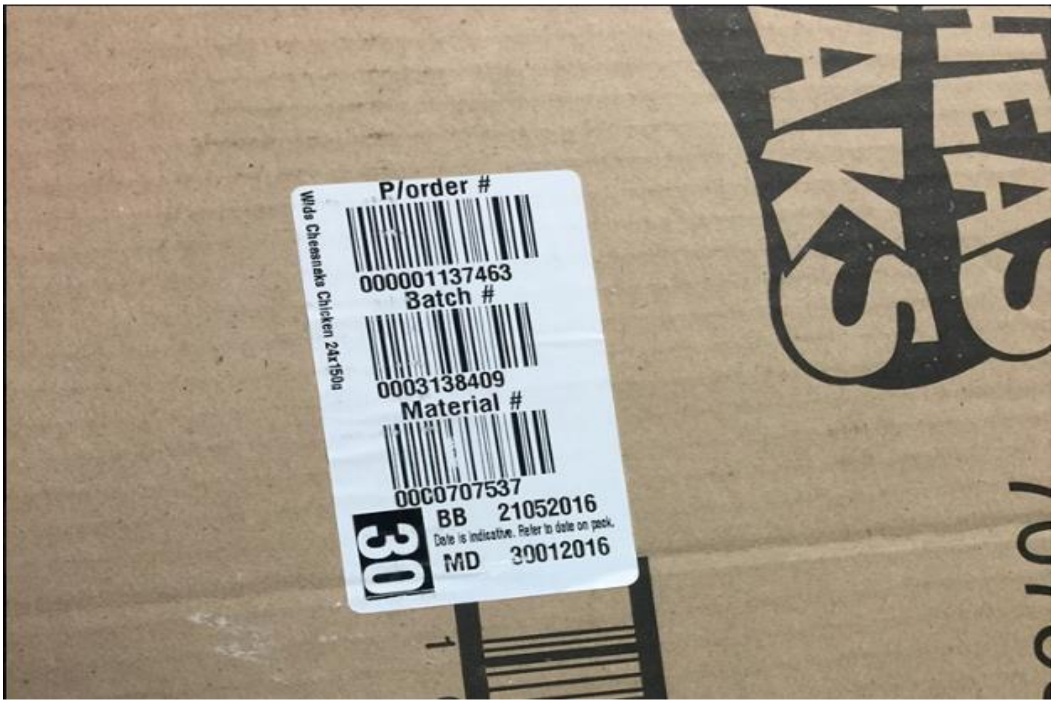


Figure 4.1 Barcode information using print-and-apply technology applied to a corrugate (28)

Repairs and maintenance costs would need to be taken into account for TTO and CIJ technology, however, for TIJ technology these costs become negligible (7). The reason for this is because TIJ technology has no moving parts (such as pumps, motors, actuators, etc.), whereas TTO and CIJ do. Such moving components over time may result in equipment wear-and-tear and on-going maintenance. Furthermore as a result of this there is an on-going requirement for engineering spare parts with TTO and CIJ technology, whereas TIJ does not typically require any engineering spare parts due to the reduced wear-and-tear experienced (3,7,28).

Consumable costs such as ribbons apply only to TTO technology while ink cartridge costs apply only to TIJ technology. Furthermore, CIJ printing may result in a messy ink application at the printhead area where the ink is dispersed, resulting in the need to acquire ink solvents to clean this. TTO would not require any ink solvents as ribbons are used rather than ink cartridges. While TIJ printing does make use of ink cartridges the printing application uses a heating process that disperses a tidy print application which does not require the use of any ink solvents. Label costs would apply only to TTO/print-and-apply technology being used on the corrugate packaging format. TIJ and CIJ technology do not require labels as their printing may be applied directly onto any packaging substrate (3,7,28).

Table 4.2 Capex and opex costs on TTO, CIJ, and TIJ technology (7)

| Capex or Opex Cost | Cost Component | TTO | CIJ | TIJ |
|---|---|---|---|---|
| Capex | Print head | Yes | Yes | Yes |
| | Installation | Yes | Yes | Yes |
| Opex | Print Technician(s) | Yes | No | No |
| | Repair and maintenance | Yes | Yes | No |
| | Engineering spare parts | Yes | Yes | No |
| | Ribbon | Yes | No | No |
| | Cartridge | No | No | Yes |
| | Solvents | No | Yes | No |
| | Label costs | Yes | No | No |
| | Depreciation on capital outlay | Yes | Yes | Yes |

The TCO calculation below is for the corrugate packaging format in Factory 1, at Company 1. Similarly, the same logic is applied to Factories 2, 3, 4 and 5 respectively for the corrugate packaging format.

TIJ equipment assumptions (47):

1. Depreciation is calculated using the straight line method over a period of 5 years.
2. Consumer price index (CPI) is assumed to be 5% year-on-year, in line with the upper band of the South African Reserve Banks target of between 3% to 6%.
3. The investment was calculated at an average exchange rate over the period at ZAR/EUR = R16.50/€1
4. The weighted average cost of capital (WACC) at Company 1 is 14%.
5. The tax implication on additional savings at Company 1 is 28%.

The total TIJ equipment proposal equates to €271 547 as shown in Table A4 in Appendix A. In order to convert to the Rand value we multiply this by the current EURO/ZAR rate of exchange, which is R16.50, giving a total value of R4 480 526.

$\therefore$ Rand value = (€271 547) x (R16.50/€1)

$\therefore$ Rand value = R4 480 526

Depreciation is now calculated on the TIJ equipment proposal using the straight line method, which ensures that the respective depreciation value remains constant for the next 5 years (47). Therefore, a depreciation value R896 105 is applied for the next 5 years as shown in Table A4 in Appendix A.

$\therefore$ Depreciation = (R4 480 526 / 5)

$\therefore$ Depreciation = R896 105

The estimated cost per print is now required and is calculated based on the trial data conducted at Factory 1 using Supplier 1, it was determined that a corrugate cartridge which currently costs R913.25 is capable of producing 53 750 prints.

Therefore the estimated cost per print, as shown in Table A2 in Appendix A, is calculated as follows:

$\therefore$ Estimated cost per print = (R913.25) / (53 750 prints)

$\therefore$ Estimated cost per print = R0.068 per print

The total opex cost per annum is now required and this is calculated by taking the estimated cost per print of R0.068 and multiplying it by the total number of corrugates cases that were used in Factory 1 over a full financial year. This data was extracted from the BI tool at Company 1 for the F16 financial year. It was determined that there were 4 369 439 corrugate cases at Factory 1. Therefore, multiplying the estimated cost per print by the number of corrugated cases produced in one financial year, as shown in Table A5 in Appendix A, equates to (47):

$\therefore$ Total opex cost per annum excluding depreciation = (R0.068) x (4 369 339 cases)

$\therefore$ Total opex cost per annum excluding depreciation = R296 685

In order to determine the total opex cost per annum including depreciation, the depreciation amount for one financial year, is added to the total opex cost excluding depreciation as shown in Table A5 in Appendix A (47).

$\therefore$ Total opex cost per annum including depreciation = (R296 685) + (R896 105)

$\therefore$ Total opex cost per annum including depreciation = R1 192 790

The next step is to sum the respective opex costs of the current (print-and-apply) printing technology in use on the corrugates at Factory 1, as show in Table A3 in Appendix A, which was pulled from Company 1's BI spend system that tracks all receipts and invoices via the organisation enterprise resource planning (ERP) system. Since Company 1 currently utilises print-and-apply technology on corrugates, all of the associated costs such as print technicians, labels, thermal transfer ribbon, repairs and maintenance, and other are then summed to give the total corrugate opex cost for year 1 at Factory 1 (47).

$\therefore$ Current opex cost in year 1 for Factory 1 = R1 465 513

The current corrugate opex cost for year 1 in Factory 1 is then given a cumulative addition of the assumed year-on-year (YoY) CPI for years 2, 3, 4, and 5 respectively. CPI is assumed at 5%, which is the upper limit of the SARB's 2016 – 2018 target of between 3% and 6%. Once all the opex costs for each respective factory have been inserted, for each of the respective 5 years going forward, the total operating costs may then be calculated in order to simplify our analysis for the next phase. This involves calculating the total incremental earnings before interest and taxes (EBIT). Table A6 in Appendix A indicates earnings before interest and taxes (EBIT) which is calculated by applying the following formula

(30,31). EBIT = revenue – operating expenses (OPEX). Since sales is zero in this case we are left with EBIT = - (OPEX).

∴ Total incremental EBIT in year 1 for Factory 1 = R0 – (R896 105 – R1 465 513)

∴ Total incremental EBIT in year 1 for Factory 1 = R569 408

Tax implications on additional savings are now taken into account and are calculated at a rate of 28% for each respective year by adding together the depreciation and total incremental EBIT for each respective year into the future, and then multiplying this amount by 28% as shown in Table A6 in Appendix A (47,48).

∴ Tax implication on additional savings in year 1 for Factory 1 = (R896 105 + R569 408) x 28%

∴ Tax implication on additional savings in year 1 for Factory 1 = R410 344

Tax allowance on machinery is now taken into consideration over a 5 year period using a ratio of 40:20:20:20 over 5 years going forward respectively. This is then calculated by multiplying the depreciation base amount (or total capex cost) by the tax implication on additional savings and then multiplying this amount by the respective tax allowance percentage, depending on the financial year under analysis as shown in Table A6 in Appendix A. For example, a tax allowance of 40% is used in year 1 for Factory 1 and is calculated as follows (47,48):

∴ Tax allowance on machinery = - (R4 480 526) x 40% x 28%

∴ Tax allowance on machinery = - R501 819

The net operating profit after tax (NOPAT) is now calculated by applying the following formula NOPAT = Operating Income x (1 - tax rate), whereby the operating income is also the EBIT. Therefore, the incremental NOPAT may be calculated by taking the total incremental EBIT and then deducting the tax implications on additional savings and the tax allowance on machinery. Hence incremental NOPAT = (total incremental EBIT) – (tax implications on additional savings) – (tax allowance on machinery). For example the incremental NOPAT in year 1 for Factory 1 may be calculated as follow as shown in Table A6 in Appendix A (47,48):

∴ NOPAT = (R569 408) - (R410 344) - (- R501 819)

∴ NOPAT = R569 408 - R410 344 - (- R501 819)

$\therefore$ NOPAT = R660 883

The next step is to calculate the incremental cash flow for each respective financial year. In order to achieve this, depreciation is now added back to the calculation for each respective financial year. The incremental cash flow baseline is calculated to be equal to the depreciation baseline, multiplied by negative 1 and then each respective years incremental cash flow is calculated by summing the incremental NOPAT, the incremental work capitalisation, and the depreciation cost, all together respectively. This is shown in Table A6 in Appendix A and is calculated for Factory 1 as follows (47,48):

$\therefore$ Incremental cash flow in year 1 for Factory 1 = R660 833 + R0 + R896 105

$\therefore$ Incremental cash flow in year 1 for Factory 1 = R1 556 988

The present value (PV) of future cash flows over 10 years is zero, since a life-cycle of 5 years is being analysed. This is then added to the incremental cash flow to determine the final incremental cash flow amount for Factory 1, as shown in Table A6 in Appendix A (47,48).

$\therefore$ Final incremental cash flow for year 1 for Factory 1 = R1 556 988 + R0

$\therefore$ Final incremental cash flow for year 1 for Factory 1 = R1 556 988

The cumulative cash flow is then calculated for each year, using the incremental cash flow figure as the base and then adding the cumulative incremental cash flow for each respective financial year, as shown in Table A6 in Appendix A (47,48).

$\therefore$ Cumulative cash flow in year 1 for Factory 1 = R1 556 988 + (-R4 480 526)

$\therefore$ Cumulative cash flow in year 1 for Factory 1 = -R2 923 538

The discount factor is then applied for each respective financial year using the following formula (47,48):

Discount factor = ($1 / 1.14^x$), whereby x = 0, 1, 2, 3, 4, 5, for the baseline, Year 1, Year 2 , Year 3, Year 4, and Year 5 respectively.

$\therefore$ Discounted cash flow factor in year 1 for Factory 1 = ($1 / 1.14^1$)

$\therefore$ Discounted cash flow factor in year 1 for Factory 1 = 0.877193

The discounted cash flow may now be calculated by multiplying the final incremental cash flow by the discounted cash flow factor for each respective financial year, hence (47,48):

∴ Discounted cash flow for baseline = (-R4 480 526) x 1.0

∴ Discounted cash flow for baseline = (-R4 480 526) x 1.0

∴ Discounted cash flow for baseline = -R4 480 526

∴ Discounted cash flow for year 1 for Factory 1 = R1 556 988 x 0.877193

∴ Discounted cash flow for year 1 for Factory 1 = R1 365 779

The net present value (NPV) is then calculated by summing the discounted cash flow from the base amount plus each respective financial year's amount, as shown in Table A6 in Appendix A (47,48).

∴ NPV for in year 1 for Factory 1 = (-R4 480 526) + (R1 365 779) + (R1 045 581) + (R954 567) + (R871 779) + (R666 124)

∴ NPV for in year 1 for Factory 1 = R423 305

The payback period (in years) may be determined by summing each respective years discounted cash flow amount, and observing when this amount is equal to, or greater than the baseline depreciation amount, or initial capex amount as shown in Table A4 in Appendix A.

∴ Capex of TIJ for Factory 1 = (€271 547) x (R16.50 / €1)

∴ Capex of TIJ for Factory 1 = R4 480 526

∴ Payback period is < 5 years

The internal rate of return (IRR) over the 5 year period can now also be calculated in excel using the IRR formula and selecting all the incremental cash flow amounts, including the baseline, as a range (47,48).

∴ IRR = 18%

Furthermore, Company 1's WACC is set at 14%.

∴ The corrugate TIJ proposal is feasible for Factory 1, since the IRR > WACC.

The return on investment (ROI) is then calculated by dividing each year's respective incremental cash flow by the baseline cash flow amount, as shown in Table A6 in Appendix A (47,48).

∴ ROI in year 1 for Factory 1 = ((R1 556 988) / -1 x (-R4 480 526)) x 100

∴ ROI in year 1 for Factory 1 = 35%

Similarly the same logic is applied to Factories 2, 3, 4 and 5 respectively, for the corrugate packaging format. Furthermore, this TCO analysis is then performed again for the carton and flexible packaging formats, however, the carton and flexible packaging formats were considered together in the TCO analysis as the current opex costs within the Company 1's BI tool contained suppliers and printing technologies that were identical across both packaging formats. This resulted in opex costs that could not be distinguished between the carton and flexible packaging formats, due to common suppliers being used on both formats. This was not the case with the corrugate packaging format, since the corrugate packaging format used only print-and-apply technology, with a designated supplier (47,48). Results from the TCO analysis will be presented and then used to determine a project rollout plan for Company 1, as certain factories present a better ROI than others. This will be analysed by the 3 main packaging formats in use at Company 1 which are corrugates, cartons, and flexibles. Based on the TCO analysis the capex investment for Company 1 was R16 988 582 as shown in Figure 4.2 below, with Factory 4 requiring the highest capex investment of R5 484 798, followed next by Factory 1 at R4 480 526, Factory 3 at R3 203 129, Factory 5 at R1 953 402 and lastly Factory 2 at R1 866 728. The below data is a summary of all factory TIJ capex costs for the corrugate packaging format as shown in Table A4 in Appendix A (47,48).

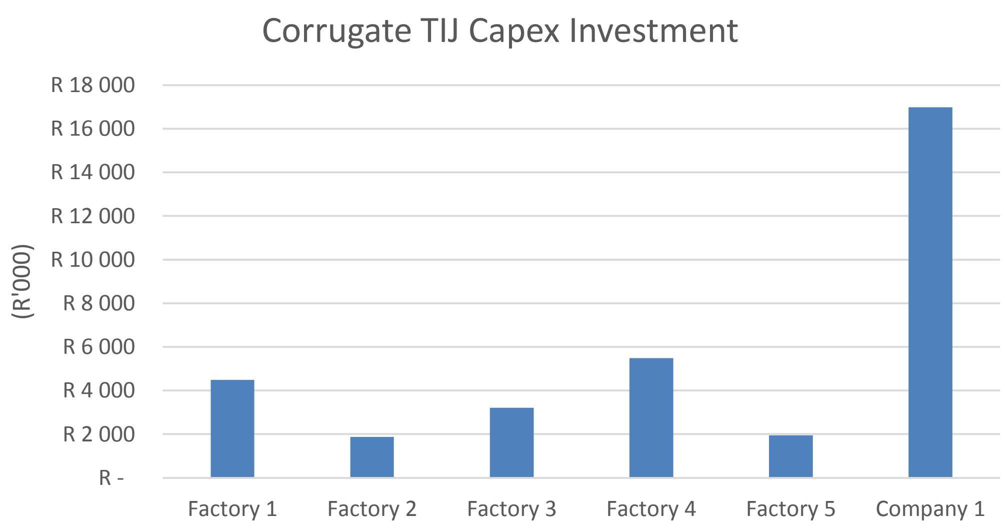


Figure 4.2 Corrugate TIJ capex spend at Company 1

Figure 4.3 is a summary of the financial measures of each factory at Company 1 with Factory 3 offering the largest net present value (NPV) of R4 653 120, followed next by Factory 4 with an NPV of R2 931 412, Factory 5 with an NPV R1 760 063, Factory 1 with an NPV of R423 305 and lastly Factory 2 with an NPV 338 282. The internal rate of return (IRR) is also indicated with Factory 3 offering the largest IRR at 65%, followed next by factory 5 at 48%, Factory 4 at 35%, Factory 2 at 21% and then Factory 1 at 18%. Factory 3 should be prioritised to transition first as it offers the highest NPV and IRR. Next to transition should be factories 4, 5, 2 and 1 respectively, as factories with the largest NPV are considered first, followed then by factories that offer the largest IRR (47,48).

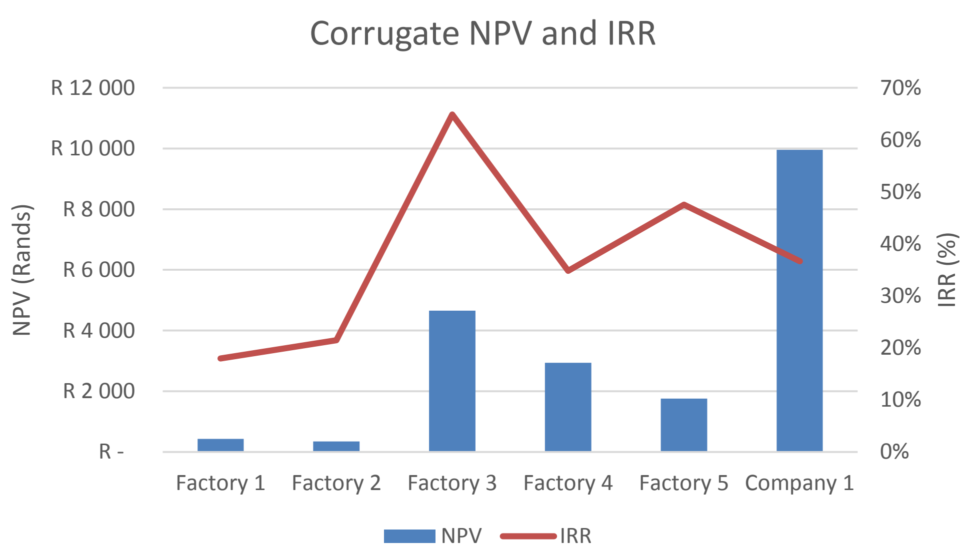


Figure 4.3 Corrugate NPV and IRR for Company 1

As a result of the prioritised NPV and IRR sequence, it can also be shown that the resulting return on investment (ROI) is also greatest for Factory 3 for the next 5 years. This is then followed by Factories 5, 4, 2 and 1 respectively, as shown in Figure 4.4. This data is a summary of each Factories respective ROI for each of the 5 years analysed. The ROI data for each Factory was calculated and summarised in Tables A6 – A10 in Appendix A (47,48).

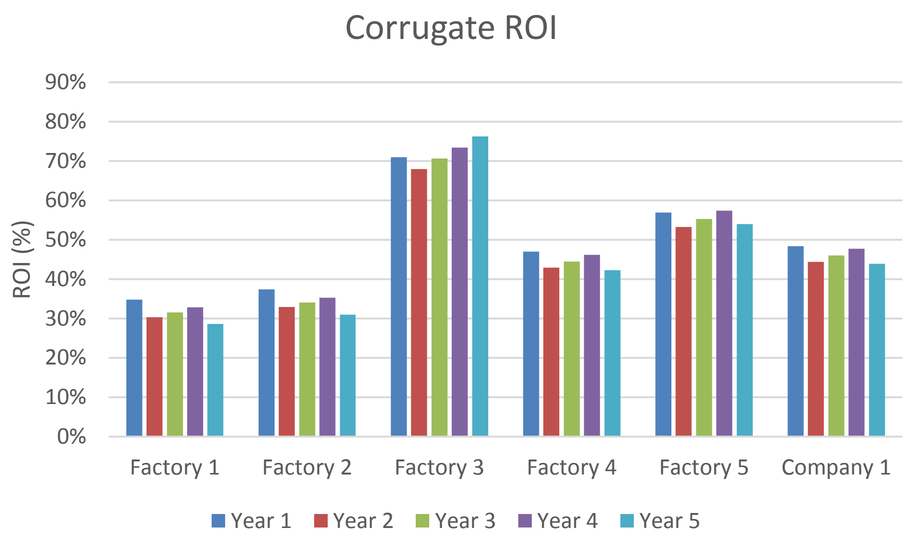


Figure 4.4 Corrugate return on investment at Company 1

The resulting annual opex saving in moving from the current corrugate print-and-apply technology in use at Company 1 is R8 766 693 as shown in Figure 4.5, however this is not an absolute saving and TIJ technology will also include opex costs for its cartridge consumption. Therefore, the annual corrugate TIJ opex costs need to be offset against the current print-and-apply technologies opex costs, in order to determine the actual net opex saving for Company 1 (47,48).

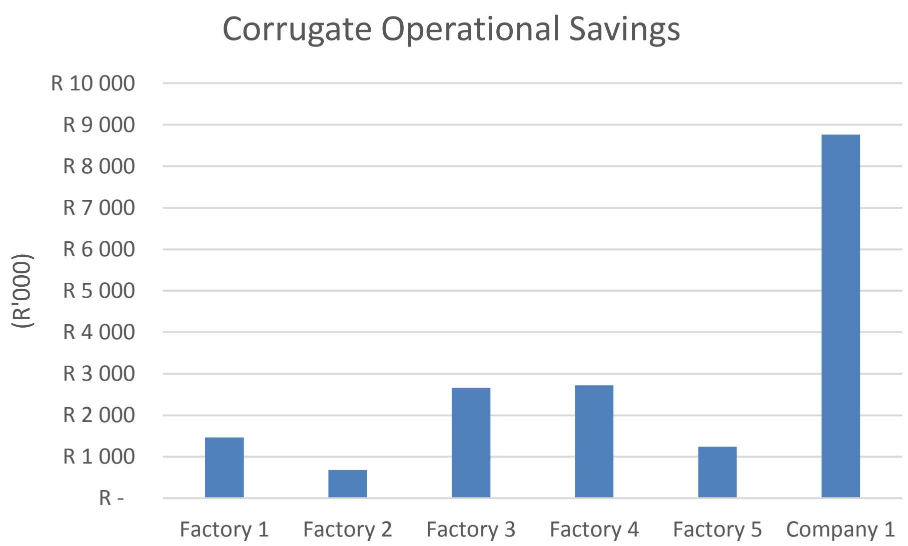


Figure 4.5 Corrugate annual operational saving

By summing the required opex costs of the proposed TIJ technology, on the corrugate packaging format, for each respective factory excluding depreciation. Therefore, the corrugate TIJ cartridge costs of each respective factory in Table A5 of Appendix A, are summed together accordingly (47,48).

∴ Opex cost on corrugate TIJ printing for each factory = R296 685 + R235 853 + R969 630 + R985 272 + R493 072

∴ Opex cost on corrugate TIJ printing for each factory = R2 980 511

∴ Net impact of corrugate TIJ opex saving can be calculated at follows:

∴ Opex saving = R8 766 693 – R2 980 511

∴ Opex saving = R5 786 182

Similar to the corrugate TCO analysis the capex investment for flexible wrap and carton packaging formats at Company 1 was R16 774 481 as shown in Figure 4.6 below, with Factory 5 requiring the highest capex investment of R4 838 261, followed next by Factory 1 at R4 148 844, Factory 4 at R3 478 541, Factory 3 at R2 478 142 and lastly Factory 2 at R1 830 693. The below data is a summary of all factory TIJ capex costs for the flexible wrap and carton packaging formats as shown in Tables B3 and B7 in Appendix B respectively (47,48).

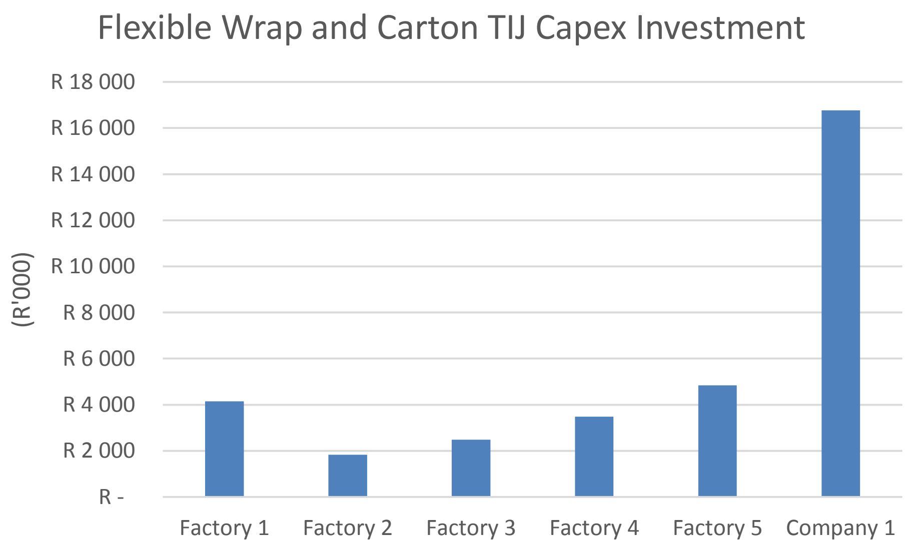


Figure 4.6 Flexible wrap and carton TIJ capex spend at Company 1

Figure 4.7 is a summary of the financial measures of each factory at Company 1 with Factory 3 offering the largest NPV of R2 177 001, followed next by Factory 4 with an NPV of R1 092 983, Factory 2 with an NPV R973 439, Factory 1 with an NPV of –R718 247 and lastly Factory 5 with an NPV –R986 649. The IRR is also indicated with Factory 3 offering the largest IRR at 47%, followed next by factory 2 at 35%, Factory 4 at 27%, Factory 1 at 6% and then Factory 5 at 5%. Factory 3 should be prioritised to transition first as it offers the highest NPV and IRR. Next to transition should be factories 4, 2, 1 and 5 respectively, as factories with the largest NPV are considered first, followed then by factories that offer the largest IRR (47,48).

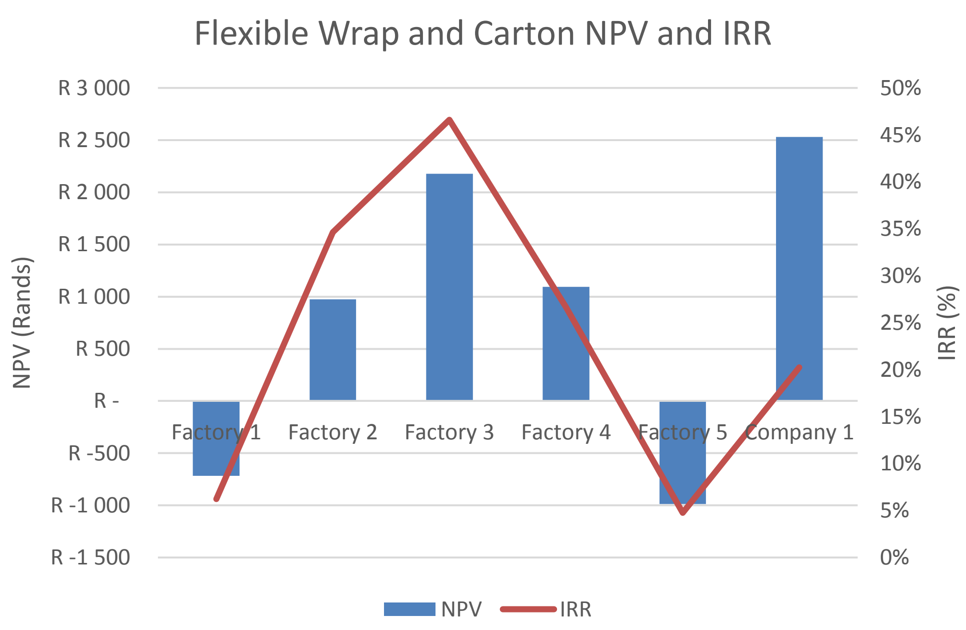


Figure 4.7 Flexible wrap and carton NPV and IRR for Company 1

As a result of the prioritised NPV and IRR sequence for the flexible wrap and carton packaging formats, it can also be shown that the resulting ROI is also greatest for Factory 3 for the next 5 years. This is then followed by Factories 2, 4, 1 and 5 respectively, as shown in Figure 4.8. This data is a summary of each Factories respective ROI for each of the 5 years analysed. The ROI data was calculated and summarised in Tables B10 – B14 in Appendix B (47,48).

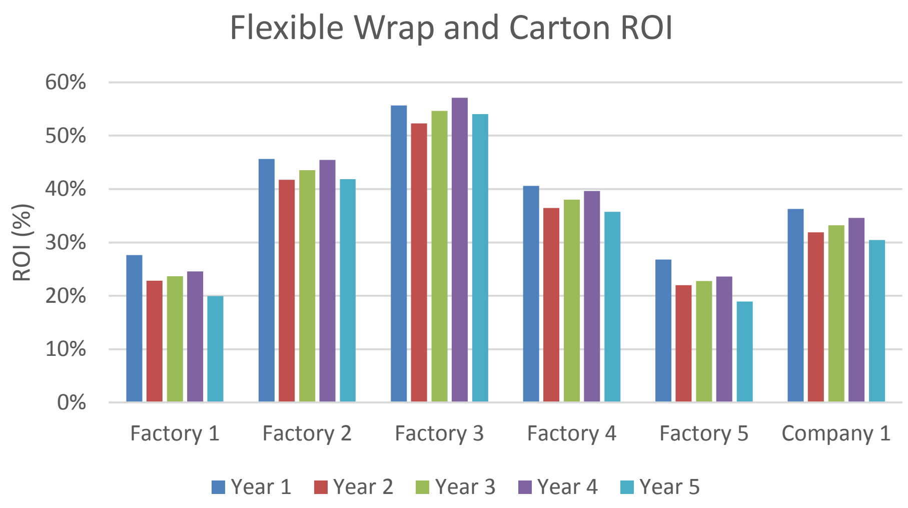


Figure 4.8 Flexible wrap and carton return on investment at Company 1

The resulting annual opex saving in moving from the current TTO and CIJ technologies in use on the flexible wraps and carton packaging format at Company 1 is R 5 837 457 as shown in Figure 4.9, however this is not an absolute saving and the TIJ technology will also include opex costs for its cartridge consumption. Therefore, the annual flexible wrap and carton TIJ opex costs need to be offset against the current TTO and CIJ technologies opex costs, in order to determine the actual net impact of opex saving for Company 1 (47,48).

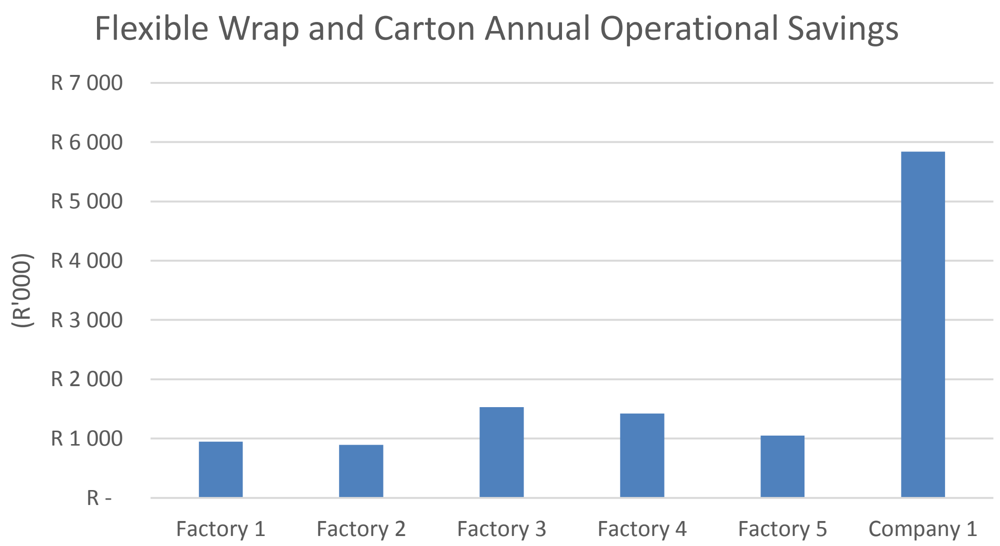


Figure 4.9 Flexible wrap and carton annual operational saving

By summing the required opex costs of the proposed TIJ technology the sum of cartridge costs on both, the flexible and carton packaging format for each respective factory excluding depreciation, is added together. Therefore, the flexible cartridge costs of each respective factory in Table B4 of Appendix B is added to the carton cartridge costs of each respective factory in Table B8 of Appendix B (47,48).

$\therefore$ Opex cost on flexible wrap and carton TIJ printing for each factory = R448 664 + R763 418 + R842 629 + R663 176 + R1 143 524 + R159 287 + R312 295 + R200 070 + R141 719 + R1 988

$\therefore$ Opex cost on flexible wrap and carton TIJ printing for each factory = R4 676 771

$\therefore$ Net impact of opex saving can be calculated at follows

$\therefore$ Opex saving = R5 837 457 – R4 676 771

$\therefore$ Opex saving = R1 160 686

## 4.3 Objective 3

The largest number of survey responses were obtained from the research and development (R&D) department within Company 1, as shown in Figure D1 in Appendix D, with a total of 4 employees from R&D completing the online survey. The next highest number of responses were obtained from the Supply Chain and Logistics departments, with 2 employees completing the survey from each department respectively. In addition to this an employee from IT, Engineering, Marketing, Projects, Finance, Manufacturing and Quality also completed the survey. Therefore a total 15 employees from Company 1 completed the survey. The results of the online survey were then presented to Supplier 1 during a face-to-face interview for purposes of vetting the validity and reliability of the results obtained.

Supplier 1 feedback was then compared to the participant feedback from the online survey and their responses are summarised in Tables 4.3 and 4.4 in order to validate the data. Explanations on all answers where Supplier 1 disagreed with the participant feedback are explained in further detail below. In addition to the feedback on the validity of the participant's online survey, Supplier 1 provided general comments on the coding and marking industry in SA, which are also summarised after Table 4.4.

Question 15 – the correct allocation of printing technologies at Company 1 should be as follows. Corrugates, cartons and horizontal-form-fill-and-seal (HFFS) flow wrapping flexible applications are best suited for TIJ technology. The vertical-form-fill-and-seal (VFFS) bagger flexible application at Factory 5 is best suited for TTO technology, while the can packaging format at Factory 4 is best suited to CIJ technology due to the significant throw distance required (49).

Question 16 – the capex outlay cost may vary depending on the technology selected, however micro piezo technology is usually the most expense capex outlay technology. This is then followed next by laser, and then TTO, TIJ and finally CIJ as certain CIJ applications have very low capex costs but high opex costs (49).

Question 17 – CIJ would normally have the lowest capex cost if an organisation were to utilise the technology for basic slow moving packaging SKUs (49).

Question 22 – The most suitable technology from the RAMS description provided is TIJ technology on corrugates, cartons and HFFS flexible flow wrapping applications. TTO is the most suitable technology for Factory 5's VFFS bagger flexible lines and lastly CIJ technology is the most suitable technology for the cans format at Factory 4 (49).

Question 26 – All technologies require replacement at some point in time but due to TIJ technology having a simple design with no moving parts it typically lasts longer than all the other technologies. Furthermore, it is a no-contact technology which relies on throw distance to print, which ultimately reduces wear-and-tear (49).

Table 4.3 Summary of participant survey results and Supplier 1's validation (part 1)

| Method | | Question No. | Coding and Marking Technology | | | | | | Supplier 1 Verification (Agree / Disagree) |
|---|---|---|---|---|---|---|---|---|---|
| | | | TIJ | TTO | CIJ | Print-and-Apply | Laser Coding | Micro Piezo | |
| RAMS | TCO | Question 6 | | | - high opex<br>- MEK used in solvents | | | | Agree |
| RAMS | TCO | Question 7 | - corrugates | - flexibles | -flexibles<br>-cans | | | | Agree |
| RAMS | TCO | Question 8 | - TIJ cartridge change is greater than 1 minute but less than 2 minutes | | | | | | Agree |
| RAMS | KPI's | Question 9 | - cartridge costs<br>- line downtime | | | | | | Agree |
| RAMS | KPI's | Question 10 | | - ribbon reel consumption<br>- repairs and support costs | | | | | Agree |
| RAMS | KPI's | Question 11 | | | - ink & solvent costs<br>- number of print defects | | | | Agree |
| RAMS | TCO | Question 12 | - low maintainance<br>- can be used on any packaging format | | | | | | Agree |
| RAMS | TCO | Question 13 | - no labels required<br>- reduced downtime and improve OE and OU | | | | | | Agree |
| RAMS | TCO | Question 14 | - A standard control system will prove more costs effective and will allow for interchanging of controllers<br>- improved OE and less training required | | | | | | Agree |
| RAMS | TCO | Question 15 | - corrugates<br>- cartons<br>- flexibles<br>- cans | - flexibles | | | | | Disagree |

| | |
|---|---|
| (yellow) | Answer not required |

Table 4.4 Summary of participant survey results and Supplier 1's validation (part 2)

| Method | | Question No. | Coding and Marking Technology | | | | | | Supplier 1 Verification (Agree / Disagree) |
|---|---|---|---|---|---|---|---|---|---|
| | | | TIJ | TTO | CIJ | Print-and-Apply | Laser Coding | Micro Piezo | |
| RAMS | TCO | Question 16 | 0 | 3 | 3 | 1 | 5 | 3 | Disagree |
| | | Question 17 | 1 | 3 | 2 | 5 | 2 | 0 | Disagree |
| | | Question 18 | - current annual opex of print-and-apply technology is more than R500 000 but less than R1 000 000 | | | | | | |
| | | Question 19 | - current annual opex of CIJ and TTO technology is greater than R2 500 000 | | | | | | |
| | | Question 20 | - average spend based on participant feedback is R4 376 000 | | | | | | |
| | | Question 21 | - average spend based on participant feedback is R4 325 000 | | | | | | |
| | | Question 22 | 13 | 13 | 13 | 12 | 12 | 12 | Disagree |
| | | Question 23 | - 13 participants responded yes and 2 particpants did not respond | | | | | | Agree |
| | | Question 24 | - corrugate artwork may be obstructing areas requiring a print<br>- corrugate line speeds may be too fast<br>- dust may clog the print-head | | | | | | Agree |
| | | Question 25 | - investigate various ink typesthat provide the best yield depending on subtrate<br>- reduce the information printed where possible<br>- reduce DPI where possible | | | | | | Agree |
| | | Question 26 | 4 | 4 | 5 | 3 | 1 | 0 | Disagree |
| | | Question 27 | - several pneumatic components that degrade over time<br>- all technologies that suffer a damaged print head would require a new print to print again (except TIJ)<br>- Contact technologies such as TTO and CIJ degrade quick than non-contact technologies | | | | | | Agree |
| | | Question 28 | 7 | 3 | 1 | 3 | 6 | 2 | Agree |
| | | Question 29 | - no moving parts<br>- maintenance free | | | | | | Agree |

| | |
|---|---|
| | Answer not required |

Supplier 1 performed a comprehensive needs analysis first, in order to determine the most suitable printing technology to be used throughout Company 1 on each of the 3 main packaging formats namely corrugates, cartons and flexibles. Furthermore Factory 4 also used a cans packaging format. Company 1 currently utilised print-and-apply technology onto all the corrugate packaging formats at each of its 5 Factories, while a combination of CIJ and TTO technology were in use on the carton, flexible and can packaging formats.

TIJ technology is significantly more economical to businesses like Company 1 from a TCO perspective. Supplier 1 were of the view that TIJ technology may have not been suggested by several of Company 1's current coding and marking suppliers, as this could be detrimental to their cash flow impact, due to the reduction in maintenance costs when using TIJ technology. Supplier 1 is unique since they are trying to introduce new customers to TIJ technology, as an alternative to common coding and marking technologies like CIJ and TTO, especially in environments where it may provide a better TCO for the customer. Supplier 1 felt that older coding technologies such as CIJ and TTO are very common in SA and while most suppliers can offer these coding and marking technologies in addition to TIJ, laser, and micro piezo, they should suggest the most suitable technology for any organisation based on a comprehensive needs analysis. This depends on various factors ranging from the packaging format being printed on, to the level of automation required within the organisation being analysed. After Supplier 1 performed a comprehensive needs analysis at Company 1, they discovered that although Company 1 currently utilises an effective combination of CIJ and TTO technology, this may not necessarily be the most optimised TCO for Company 1 in the long term.

Several of today's coding and marking suppliers are owned by Danaher. There is often a misconception, with customers thinking that if they move away from Videojet and use Domino or Linx printers, there will be a difference in technology, however, all 3 of these suppliers mentioned are owned by the same organisation. Furthermore Videojet bought out Wolke who were once the largest suppliers of TIJ technology in the world. Hence this effectively means Danaher also have the capability to promote TIJ technology but they choose not to since this is not driving their profit margin the way CIJ technology would (49,50).

Supplier 1 is also on a drive to move towards ‘Industry 4.0’, which involves a new level of automation within the coding and marking industry in SA. The goal is to have a completely maintenance free solution with constant software updates that enable better performance based on Company 1’s unique printing requirements. Software updates can also be done remotely too, provided there is an internet connection with reliable bandwidth (49,50). The first major competitive edge that supplier 1 has, is the control mechanism that is used on all of its printing technologies. The control mechanism, which is known as ‘Titan’, is a unified interface that is used throughout Supplier 1’s coding and marking technologies. Therefore any coding technology supplied by supplier 1 will have a standardised data communication via the customers ERP system. Furthermore integration with the ERP system is only required once during installation, whereas other suppliers require developers and PLC programmers to come and install their technologies which in most instances use a separate control mechanism for each printing technology (49,50).

Supplier 1 will continue to first consult with the customer and then complete a stringent fact-find and needs analysis, in order to determine the most suitable coding and marking technology for the customer. While this may reveal several coding and marking technology options, the most suitable TCO solution for the customers’ requirements will always be selected in order to ensure customer satisfaction. TIJ technology can also work on the carton packaging format at Company 1. Initially a solvent-based ink will be used, however, this can be changed to a water-based ink if the customer is able to have their cartons printed with a lacquer free section, for the TIJ printers to print on. TIJ technology is also a digital technology that offers a high printing resolution of up to 600x600 DPI. According to Supplier 1 this will assist in deterring counterfeit products, since codes and tracking data that are being printed can be instantaneously changed. A 2D code is significantly more robust than a 1D barcode as it holds significantly more data.

TIJ may encounter problems of static on flexible applications. For example, when flexible film reels travel over rollers on the flexible packaging lines, static charge is sometimes generated and this charge may affect adhesion from the TIJ printer. During printing with TIJ technology the main drop of ink that gets dispersed is capable of penetrating the static field surrounding it, however, there is instances where a satellite drop of ink breaks away from this main drop. Due to this satellite drop being so small, it is not capable of breaking through the surrounding static field and as a result, it is then fired back into the printheads orifice which over time accumulates ink and gets damaged (49,50).

Supplier 1 also controls the manufacturing and development of their equipment and inks. The TIJ technology proposed by supplier 1 allows for refilling of the ink cartridge. Currently Supplier 1 is the only supplier that is allowed to refill the ink cartridge once used, however this will not be done for Company 1, as there is concern that the quality of the print may be affected. Supplier 1 have also developed a unique chipset that each ink cartridge carries. This chipset provides control over the ink cartridge capacity levels and disperse parameters. This is another instance of where software updates play a critical role as the chip enables heating to vary depending on the packaging format and ink being used. For instance, 100°C may be used on one ink cartridge type providing the highest DPI and largest ink saving while 80°C may be a more suitable heating temperature on another ink cartridge type, in order to obtain the same result (49,50) .

The market in SA has a negative view of the TIJ industry, as in many instances, a potential supplier will propose CIJ technology while simultaneously criticising TIJ technology. This is often deliberate as suppliers are often fully aware that TIJ technology does not have on-going maintenance costs for the customer, hence once the solution is implemented there is no further costs being charged to the customer until there is a need to install it again at the end of its life span. CIJ technology will however, ensure on-going cash flow through its high maintenance costs, hence the reason that most suppliers propose it as they are reliant on this cash flow for their profitability. This is why a needs analysis is so critical to the customer and also why in most instances, one is never performed with the customer. While the products offered by Supplier 1 have a modular design as well as a standard control user interface (a.k.a. Titan), the unique difference for Supplier 1 is that once a comprehensive needs analysis and fact find has been performed, the most suitable solution will be proposed for the customer (49,50).

# CHAPTER 5 DISCUSSION

This chapter discusses impact of the implementation of thermal ink jet (TIJ) technology in a selected fast moving consumer goods (FMCG) organisation in SA, namely Company 1. This is done by firstly discussing the current and future printing technology key performance indicators (KPIs) that are most critical to the success of the selected FMCG organisation in South Africa through the use of the reliability, availability, maintainability and safety (RAMS) methodology for all the main printing technologies used in SA. Secondly, a discussion is made with respect to the financial feasibility of the selected company using the total cost of ownership (TCO) analysis, assuming Company 1 were to invest in thermal ink jet (TIJ) technology throughout each of its 5 factories. Thirdly, analysis of the results of the online survey which were distributed to employees within Company 1 and which incorporates both the RAMS and TCO methodologies, through a conceptual decision making framework, are also discussed in order to obtain their feedback on the most suitable printing technology mix. Finally, the results to the online survey are discussed with Supplier 1, for purposes of reliability and validity as part of the selection process, should Company 1 decide to invest in TIJ technology.

## 5.1 Evaluating the RAMS Framework

Using the RAMS methodology as a basis it can be shown that the most critical KPIs from a current and future reliability perspective include line downtime and overall equipment effectiveness (OEE) as previously shown in Table 4.1. This applies to each of the main printing technologies considered namely continuous ink jet (CIJ), thermal ink jet (TIJ), thermal transfer overprinting (TTO), print-and-apply, laser, and micro piezo. Line downtime represents any potential reliability issues that may result in the respective printing technology not operating during its intended shift. Similarly OEE is also an important metric that will assist in identifying any losses, print defects, benchmarking progress and improving productivity. The most critical current and future KPIs from an availability perspective include operational efficiency (OE), operational utilisation (OU) and working capital. The OE metric works hand-in-hand with OU which is defined as the total capacity or shift time available in the factory. Therefore a higher OE is maintained with a higher OU since less stop/starts are required which may affect the OE.

Often line stoppages are unavoidable and may be due to reasons that are completely unrelated to the printing technology. For instance, there may be a change in SKU, or line cleaning which would therefore cause a reduction in OU and hence also OE, however this is often process related and can therefore be justified by setting a benchmark of 90% instead of 100%. In real world applications it can be shown that 90% is effectively the best OE that can be achieved, however this needs to be adjusted by each respective printing technologies packaging line. Working capital is another metric which gets affected on all printing technologies except TIJ technology, since all the other technologies require maintenance, hence the working capital is indirectly affected. This is due to spare component parts or extra printers being stored as a backup unit(s) which affects the working capital (43,47,48).

Furthermore, the various tools and techniques that allow for selection of the most suitable printing technology from a RAMS perspective, may also be applied. The mean time to failure (MTTF) and mean time between failures (MTBF) are the most suitable measurements at understanding the reliability aspects of the various technologies in use. The most suitable KPIs will therefore remain line downtime and OEE, regardless of the technology in use. From Table 2.4, the two most suitable printing technologies in this regard are TIJ and TTO technology. Availability and safety can also be assessed through the use of failure mode and effects analysis (FMEA), as well as through failure mode effects and criticality analysis (FMECA) respectively. These techniques indicate that the most suitable printing technologies are TIJ and TTO, as both offer improved OE and OU, which ultimately will result in a valuable output with reduced downtime respectively.

Safety requires no immediate KPIs as both TIJ and TTO are safe for the end-user and the environment (43,47,48). There is no harmful chemical or ink solvent in either of these technologies. Similarly, redundancy and Pareto analysis are tools that can assist in determining the maintainability aspect of RAMS. Here TIJ technology is the most suitable technology on corrugates, cartons and horizontal-form-fill-and-seal (HFFS) flexible flow wrapping applications, while TTO is more suitable on vertical-form-fill-and-seal (VFFS) bagger flexible applications. Redundancy plays a critical part especially with standardisation across TIJ technology due to its modular design, which includes a TIJ cartridge, printhead, photocell, cable and controller as the main components. Here the most critical KPIs are ink cartridge costs and ribbon reel costs (or consumable costs) for both TIJ and TTO technology respectively. While perhaps not as significant as the other technologies, TTO does have a maintenance cost associated with its thermal transfer ribbon reel holder and printhead. While maintenance always exists to some extent, with TIJ this is negligible in most instances. Pareto analysis will confirm that the majority of the maintainability KPIs are due to the consumables used in both technologies (31-34).

## 5.2 TCO Analysis

Based on the TCO analysis the capex investment for Company 1 was R16 988 582 as shown in Figure 4.2, with Factory 4 requiring the highest capex investment of R5 484 798, followed next by Factory 1 at R4 480 526, Factory 3 at R3 203 129, Factory 5 at R1 953 402 and lastly Factory 2 at R1 866 728. This data is a summary of each Factories TIJ capex costs for the corrugate packaging format as shown in Table A4 in Appendix A (47,48). Figure 4.3 indicates the financial measures of each factory at Company 1 using tables A6 – A10 in Appendix A. Factory 3 offers the largest net present value (NPV) of R4 653 120, followed next by Factory 4 with an NPV of R2 931 412, Factory 5 with an NPV R1 760 063, Factory 1 with an NPV of R423 305 and lastly Factory 2 with an NPV 338 282. The internal rate of return (IRR) was also calculated with Factory 3 offering the largest IRR at 65%, followed next by factory 5 at 48%, Factory 4 at 35%, Factory 2 at 21% and then Factory 1 at 18%. Factory 3 should be prioritised to transition first as it offers the highest NPV and IRR. Next to transition should be factories 4, 5, 2 and 1 respectively, as factories with the largest NPV are considered first, followed next by factories that offer the largest IRR (47,48).

As a result of the prioritised NPV and IRR sequence, it can also be shown that the resulting return on investment (ROI) is also greatest for Factory 3 for the next 5 years. This is then followed by Factories 5, 4, 2 and 1 respectively, as shown in Figure 4.4. This data is a summary of each Factories respective ROI for each of the 5 years analysed. The ROI data was calculated and summarised in Tables A6 – A10 in Appendix A (47,48). The resulting annual opex saving in moving from the current corrugate print-and apply technology in use at Company 1 is R8 766 693 as shown in Figure 4.5, however this is not an absolute saving as the TIJ technology implementation will also include opex costs for its cartridge consumption. Therefore, the annual corrugate TIJ opex costs need to be offset against the current print-and-apply technologies opex costs, in order to determine the actual net opex saving for Company 1 (47,48). By summing the required opex costs of the proposed TIJ technology, on the corrugate packaging format, for each respective factory excluding depreciation. Therefore, the corrugate TIJ cartridge costs of each respective factory in Table A5 of Appendix A, are summed together accordingly providing a total opex cost on corrugates of R2 980 511. This amount is then deducted from the annual opex saving when using TIJ technology. This results in a total opex saving of R5 786 182 at Company 1 (47,48).

Similar to the corrugate TCO analysis the capex investment for the flexible wrap and carton packaging formats at Company 1 was R16 774 481 as shown in Figure 4.6, with Factory 5 requiring the highest capex investment of R4 838 261, followed next by Factory 1 at R4 148 844, Factory 4 at R3 478 541, Factory 3 at R2 478 142 and lastly Factory 2 at R1 830 693. Figure 4.7 is a summary of the financial measures of each Factory at Company 1 on the carton and flexible packaging formats, using Tables B10 – B14 in Appendix B. Factory 3 offers the largest NPV of R2 177 001, followed next by Factory 4 with an NPV of R1 092 983, Factory 2 with an NPV R973 439, Factory 1 with an NPV of –R718 247 and lastly Factory 5 with an NPV –R986 649. The IRR is also indicated with Factory 3 offering the largest IRR at 47%, followed next by factory 2 at 35%, Factory 4 at 27%, Factory 1 at 6% and then Factory 5 at 5%. Factory 3 should be prioritised to transition first as it offers the highest NPV and IRR. Next to transition should be factories 4, 2, 1 and 5 respectively, as factories with the largest NPV are considered first, followed then by factories that offer the largest IRR (47,48).

As a result of the prioritised NPV and IRR sequence for the flexible wrap and carton packaging formats, it can also be shown that the resulting ROI is also greatest for Factory 3 for the next 5 years. This is then followed by Factories 2, 4, 1 and 5 respectively, as shown in Figure 4.8. This data is a summary of each Factories respective ROI for each of the 5 years analysed. The ROI data was calculated and summarised in Tables B10 – B14 in Appendix B (47,48). The resulting annual opex saving in moving from the current TTO and CIJ technologies in use on the flexible wraps and carton packaging format at Company 1 is R 5 837 457 as shown in Figure 4.9, however this is not an absolute saving and the TIJ technology will also include opex costs for its cartridge consumption. Therefore, the annual flexible wrap and carton TIJ opex costs need to be offset against the current TTO and CIJ technologies opex costs, in order to determine the actual net impact of opex saving for Company 1 (47,48). By summing the required opex costs of the proposed TIJ technology the sum of cartridge costs on both, the flexible and carton packaging format for each respective factory excluding depreciation, is added together. Therefore, the flexible cartridge costs of each respective factory in Table B4 of Appendix B is added to the carton cartridge costs of each respective factory in Table B8 of Appendix B which equates to R4 676 771. This amount is then deducted from the annual opex saving when using TIJ technology, resulting in a total opex saving of R1 160 686 at Company 1 (47,48).

## 5.3 Survey Results

Results from the online survey, based on the conceptual decision-making framework as shown in Table 3.1 – developed by incorporating the RAMS and TCO methodologies for each of the printing technologies – indicated that employees in Company 1 felt that TIJ and TTO were the best suited printing technology combination for the packaging formats analysed. Furthermore Company 1 employee feedback indicated TIJ technology would definitely be a better alternative to Company 1's current corrugate print-and-apply application, which printed 3 barcodes onto a label. With TIJ technology all 3 barcodes may be merged directly into one 2D barcode, without the need for any label as TIJ technology can print on nearly all substrates. As a result, this would simplify the scanning procedure for the warehouse picker as he/she will not need to proactively look to determine which barcode to scan, as scanning one 2D code will carry all the necessary information that is required to competently warehouse manage the stock.

While Company 1 currently does utilise scanners that have 2D scan capability, this change can be implemented as part of an on-going drive to reduce the TCO whilst maintaining all the necessary requirements from a RAMS perspective. As a result if Company 1 were to move its corrugate data printing onto TIJ technology, any 1D type laser based scanners may eventually become obsolete, as they will only be capable of scanning linear barcodes that hold text only. Furthermore, TIJ implementation at Company 1 is also likely to result in improvements to the end customer's entire supply chain process. Therefore by changing the current CIJ, TTO and print-and apply technology in Company 1 to TIJ technology and TTO technology, several operational areas of the organisation, from warehouse management to line OE, can also be improved upon.

## 5.4 Validity and Reliability

The results from the online survey were also presented to Supplier 1 (as shown in Tables 4.3 and 4.4) in order for Supplier 1 to verify if this combination of printing technologies would be suitable for Company 1. While Supplier 1 was capable of supplying any of the printing technologies analysed in this research, they too were of the view that the ideal printing technology mix for Company 1, should include TIJ and TTO technology, as per the employee survey feedback. This also reinforces findings based on the critical KPIs and on the ideal printing technology mix for specific substrates from the RAMS framework, which determined that TIJ technology is the most suitable technology for the corrugate, carton and horizontal-form-fill-and-seal (HFFS) flow wrapper packaging lines. The only exception was in instances where the flexible packaging lines follow a vertical-form-fill-and seal (VFFS) bagger packaging arrangement, which proves better suited toward TTO technology. Supplier 1 emphasises that this was particularly noticed in Factory 5 which consisted of several VFFS bagger packaging lines, whereby TTO technology is more suitable than TIJ technology (25).

The reason for this is while these lines have a high volume of packaging passing through them, their speed is slower than the HFFS flow wrapper packaging lines found within Factories 1 – 4, which are better suited towards TIJ technology. Furthermore TTO is also a contact solution and these VFFS bagger packaging lines will stop and start more frequently than the HFFS flow wrapper packaging lines making TTO a better coding selection than TIJ technology for these specific applications. The disadvantage of TTO technology is that it is not a modular technology and the printhead will require replacement as wear-and-tear plays a larger role due to it being a contact solution, with vibration slowly degrading the printhead over time. The slow degradation of the TTO printhead may also result in dust clogging, which leads to prints that have pixels missing which can impact scanning too (especially in instances of print-and apply) applications on corrugates. Another advantage if Company 1 were to deploy TIJ technology across the 3 main packaging formats is that, with the system being modular, all equipment components are unified across each packaging formats application. The only difference is the ink type since the HFFS flexible wraps will utilise solvent-based ink cartridges, whereas the carton and corrugates will utilise water-based ink cartridges.

The TCO results also indicate that TIJ technology is the most suitable coding and marking technology for use on the corrugate and carton packaging formats at Company 1. Furthermore the HFFS flexible application is also better suited towards TIJ technology from a TCO perspective, however, the VFFS flexible application is better suited towards TTO technology. Based on literature and Supplier 1 feedback, coding and marking technology has been slow to change in SA. Several of the coding and marking suppliers today are owned by Danaher who could promote TIJ technology, but choose not to since this is not driving their profit margin the way CIJ technology will, due to the on-going maintenance required (49,50). TIJ technology is significantly more economical to businesses like Company 1 from a TCO perspective and while Company 1 currently does utilise an effective combination of CIJ and TTO technology, this is not the most optimised printing technology mix for Company 1 in the long term.

# CHAPTER 6 CONCLUSIONS

The following conclusions may be drawn from this research:

- Ink jet methods have the potential to significantly increase the range of functions in micromanufactured devices due to the additive, non-contact, digital nature of the technology, which also results in a lower production cost and in reduced environmentally unfriendly waste.
- Previously organisations looking for a coding and marking technology to print barcodes, expiry date, manufacturing date, and other critical information had only one major printing technology to consider, namely CIJ. It could print on almost everything, ranging from plastics to metal, however, this came at a price which involved a complex operation, costly downtime, and the hazardous risk of using various ink solvents. Today, however, there is an alternative in the form of TIJ technology, which manages to overcome each of the problems previously encountered.
- The benefit of implementing TIJ printing technology, in addition to a reduction in the total cost of ownership (TCO), would be to also reduce complexity and maintenance, due to a general lack of skill on the factory floor at Company 1.
- Thermal transfer overprinting (TTO) technology is a more suitable printing technology on flexible wraps running on the vertical-form-fill-and-seal (VFFS) bagger packaging lines, while thermal ink jet (TIJ) technology is more suitable on the horizontal-form-fill-and-seal (HFFS) flow wrapper packaging lines.
- While the barcodes used by Company 1 are primarily for warehouse management purposes, there is also legal requirement for track and traceability of products in order to manage consumer risk, hence the requirement for barcodes that contain information in a robust and compact format.
- Micro piezo printing will deliver a better TCO than TIJ technology on the corrugate packaging format in instances where a large amount of ink is required for more than track and traceability purposes, however, micro piezo printing technology should only be deployed once an organisation is satisfied that there is adequate skill on the factory floor to operate and maintain the printers, since micro piezo printers require significantly more skill to operate when compared to other printing technologies.

- TIJ technology is the most feasible technology for Company 1's corrugate packaging format, since the current requirement was to find a more feasible alternative to print-and-apply technology, which currently prints 3 barcodes onto a label that gets applied onto a corrugate.
- Alternatively micro piezo technology would most likely be more feasible than TIJ technology on Company 1's corrugate packaging format, if the requirement were to arise to print the stock keeping units (SKUs) artwork onto the corrugate, in addition to the 3 barcodes used for track and traceability.
- TIJ technology should always maintain a competitive edge over all other printing technologies due to its maintenance free design.
- Continuous ink jet (CIJ) technology is potentially harmful to both the user and the environment due to its consumable requirements of ink plus solvents that include methyl-ethyl-ketones (MEK).
- Key performance indicators (KPIs) that effectively measure the performance of TIJ technology include cartridge costs, line downtime and line operational efficiency (OE).
- KPIs that effectively measure the performance of TTO technology include ribbon reel length consumption, line downtime, repairs and support, and line OE.
- KPIs that effectively measure the performance of CIJ technology include ink and solvent costs, maintenance costs, line downtime, and working capital (or number of spare back-up printers).
- Supplier 1 should continue to have a competitive edge in their coding and marking solutions, as their 'Titan' control platform ensures user-friendly operation for any customer utilising any available printing technology.
- Increased second phase TCO benefits that may be utilised with TIJ technology, include reducing the dots per inch (DPI), moving from a 1D to a 2D barcode design on the corrugate packaging format and finally eliminating the need for any on-site support.
- The 2 main reasons why TTO remains the most suitable printing technology on the VFFS bagger packaging lines, such as those used in Factory 5, is due to:
    - The unit cost for CIJ inks and solvents has become cost prohibitive.
    - Solvent ink technology for TIJ printers has not always been able to offer the adhesion and rub resistance required for multi-laminate plastic films.

- The downside to TTO technology remains the relatively high cost of capital and downtime for ribbon changes, as well as the on-going maintenance costs which are not insignificant, however they are less than that of CIJ technology.
- When using TIJ technology, it is important to consider the KPIs that measure the true performance of the inks required for the necessary applications which include:
    - Print head recovery time – allowing for delays between printing if required without the need for purging.
    - High rub resistance of prints which is critical for manufacturers and retailers so that the prints don't get rubbed off too easily.
    - Throw distance in instances where application on VFFS baggers and HFFS flow wrappers are being printed on.

# CHAPTER 7 RECOMMENDATIONS AND FUTURE RESEARCH

- While printing technologies such as thermal transfer overprinting (TTO) are specifically designed for flexible printing applications, the printhead does come into direct contact with the packaging surface since it is based on a mechanical touch based application. This will result in a higher total cost of ownership (TCO) than thermal ink jet (TIJ) technology as more frequent maintenance and repairs will be required due to increased wear and tear in the long term. TIJ technology is therefore the best option for flexible packaging lines using a horizontal form-form-fill-and-seal (HFFS) arrangement such as those used in Factories 1, 2, 3 and 4.
- When taking into account the speed limitations of various printing technologies it can be seen that while TTO may perform well initially on the HFFS flow wrapper packaging lines, with a very low consumable cost, this is likely to change with maintenance costs escalating rapidly at a point in time. Therefore, the TCO over the entire life cycle of the printing technology should be considered before implementation.
- In addition to the above point, when also taking into account the reliability, availability, maintainability and safety (RAMS) framework of both TIJ and TTO technology, TIJ proves to be more suitable than TTO on the HFFS flexible packaging lines, however TTO is more suitable than TIJ on the vertical-form-fill-and-seal (VFFS) flexible packaging lines such as those used in Factory 5.
- It is critical for the on-boarding coding and marking supplier to perform a comprehensive fact-find and needs analysis, in order to determine the most suitable printing technology for the customer, especially from a RAMS and TCO perspective.
- Suppliers 1's end-user control mechanism (known as 'Titan') utilises a standardised user interface regardless of the packaging substrate or printing technology being used. This will minimise training and reduce operator error on the factory floor, since the technology remains consistent.
- Corrugate TIJ printing technology should be implemented on factories with the highest NPV, IRR and ROI respectively, hence factory 3 should be done first, followed then sequentially by factories 4, 5, 1 and 2, respectively.

- Similarly the flexible wrap and carton TIJ printing should be implemented on factories with the highest NPV, IRR and ROI respectively, hence factory 3 should be done first, followed then sequentially by factories 4, 2, 1 and 5, respectively.
- It is anticipated that a similar capex rollout plan which includes RAMS and TCO analysis, should apply to other FMCG organisations within Gauteng that utilise the same packaging formats as those used in Company 1. This requires further research to confirm the hypothesis.

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## APPENDIX A CORRUGATE TOTAL COST OF OWNERSHIP

Table A1 Number of TIJ printers required for Company 1's corrugate packaging format

| Factory | Corrugate Printers | Corrugate Printer Cost | Corrugate Manual Adjust Printers | Corrugate Manual Adjust Printer Cost | Corrugate Auto Adjust | Corrugate Auto Adjust Printer Cost | Corrugate Bolt On | Corrugate Bolt On Printer Cost | Corrugate Special | Corrugate Special Printer Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Factory 1 | 11 | € 6 875 | 10 | € 17 012 | 0 | € 18 980 | 0 | € 10 062 | 1 | € 25 806 | € 271 547 |
| Factory 2 | 4 | € 6 875 | 2 | € 17 012 | 0 | € 18 980 | 0 | € 10 062 | 2 | € 25 806 | € 113 135 |
| Factory 3 | 9 | € 6 875 | 6 | € 17 012 | 0 | € 18 980 | 3 | € 10 062 | 0 | € 25 806 | € 194 129 |
| Factory 4 | 14 | € 6 875 | 14 | € 17 012 | 0 | € 18 980 | 0 | € 10 062 | 0 | € 25 806 | € 334 412 |
| Factory 5 | 5 | € 6 875 | 1 | € 17 012 | 3 | € 18 980 | 1 | € 10 062 | 0 | € 25 806 | € 118 387 |

Table A2 Estimated TIJ cost per print for Company 1's corrugate packaging format

| Factory | Number of Prints per Corrugate Cartridge | Corrugate Cartridge Cost | Cost per Print |
|---|---|---|---|
| Factory 1 | 53 750 | R 913.25 | R 0.0680 |
| Factory 2 | 53 750 | R 913.25 | R 0.0680 |
| Factory 3 | 53 750 | R 913.25 | R 0.0680 |
| Factory 4 | 53 750 | R 913.25 | R 0.0680 |
| Factory 5 | 53 750 | R 913.25 | R 0.0680 |

Table A3 Opex cost of current corrugated printing technology at Company 1

| Cost Type | Spend Cube Cost Components | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| Opex | Print technicians | R 791 896 | R 237 569 | R 824 355 | R 1 189 844 | R 475 138 |
| | Continuous ink jet labels | R 417 725 | R 277 965 | R 921 517 | R 978 582 | R 756 156 |
| | Continuous ink jet solvents | R - | R - | R - | R - | |
| | Thermal transfer ribbon | R 245 581 | R 163 692 | R 279 957 | R - | |
| | Repairs and maintenance | R 10 311 | R - | R 622 449 | R - | R 7 490 |
| | Parts | R - | R - | R - | R - | |
| | Support and call out | R - | R - | R - | R - | |
| | Other | R - | R - | R 11 623 | R 554 844 | |
| | **Total** | **R 1 465 513** | **R 679 226** | **R 2 659 901** | **R 2 723 270** | **R 1 238 784** |

Table A4 Capex costs of TIJ printing technology on Corrugates at Company 1

| Cost Type | Cost Component | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| Capex | TIJ Equipment Proposal | € 271 547 | € 113 135 | € 194 129 | € 332 412 | € 118 388 |
| | Rate of exchange (ROE) | R 16.50 | R 16.50 | R 16.50 | R 16.50 | R 16.50 |
| | | R 4 480 526 | R 1 866 728 | R 3 203 129 | R 5 484 798 | R 1 953 402 |
| | Amortisation per annum | R 896 105 | R 373 346 | R 640 626 | R 1 096 960 | R 390 680 |

Table A5 Opex costs of TIJ printing technology on Corrugates at Company 1

| Cost Type | Cost Component | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| | Estimated cost per label | R 0.068 | R 0.068 | R 0.068 | R 0.068 | R 0.068 |
| | Annual number of corrugated case prints | 4 369 439 | 3 473 532 | 14 280 260 | 14 510 627 | 7 261 733 |
| **Total opex cost per annum excluding depreciation** | | **R 296 685** | **R 235 853** | **R 969 630** | **R 985 272** | **R 493 072** |

| | | | | | |
|---|---|---|---|---|---|
| **Total opex cost per annum including depreciation** | **R 1 192 790** | **R 609 198** | **R 1 610 255** | **R 2 082 231** | **R 883 752** |

Table A6 TCO analysis of Factory 1 using TIJ printing on corrugates

| Factory 1 TIJ Corrugated Printing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 4 481 | R 896 | R 896 | R 896 | R 896 | R 896 |
| Spend cube operating cost total | R -1 466 | R -1 466 | R -1 539 | R -1 616 | R -1 697 | R -1 781 |
| Total incremental EBIT | | R 569 | R 643 | R 720 | R 800 | R 885 |
| Tax implication on additional savings | 28% | R 410 | R 431 | R 452 | R 475 | R 499 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -502 | R -251 | R -251 | R -251 | R - |
| Incremental NOPAT | | R 661 | R 463 | R 518 | R 576 | R 386 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 896 | R 896 | R 896 | R 896 | R 896 |
| Incremental cash flow | R -4 481 | R 1 557 | R 1 359 | R 1 414 | R 1 472 | R 1 283 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -4 481 | R 1 557 | R 1 359 | R 1 414 | R 1 472 | R 1 283 |
| Cumulative cash flows | R -4 481 | R -2 924 | R 2 916 | R 2 773 | R 2 887 | R 2 755 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -4 481 | R 1 366 | R 1 046 | R 955 | R 872 | R 666 |
| WACC | 14% | | | | | |
| NPV | R 423 | | | | | |
| Payback period | < 5 years | | | | | |
| 10 years IRR | 18% | | | | | |
| Annual ROI (initial investment) | | 35% | 30% | 32% | 33% | 29% |

Table A7 TCO analysis of Factory 2 using TIJ printing on corrugates

| Factory 2 End of Line Printing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 1 867 | R 373 | R 373 | R 373 | R 373 | R 373 |
| Spend cube operating cost total | R -679 | R -679 | R -708 | R -738 | R -770 | R -803 |
| Total incremental EBIT | | R 306 | R 335 | R 365 | R 397 | R 430 |
| Tax implication on additional savings | 28% | R 190 | R 198 | R 207 | R 216 | R 225 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -209 | R -105 | R -105 | R -105 | R - |
| Incremental NOPAT | | R 325 | R 241 | R 263 | R 286 | R 205 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 373 | R 373 | R 373 | R 373 | R 373 |
| Incremental cash flow | R -1 867 | R 698 | R 614 | R 636 | R 659 | R 578 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -1 867 | R 698 | R 614 | R 636 | R 659 | R 578 |
| Cumulative cash flows | R -1 867 | R -1 169 | R 1 313 | R 1 251 | R 1 295 | R 1 237 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -1 867 | R 612 | R 473 | R 429 | R 390 | R 300 |
| WACC | 14% | | | | | |
| NPV | R 338 | | | | | |
| Payback period | < 4 years | | | | | |
| 10 years IRR | 21% | | | | | |
| Annual ROI (initial investment) | | 37% | 33% | 34% | 35% | 31% |

Table A8 TCO analysis of Factory 3 using TIJ printing on corrugates

| **Factory 3 End of Line Printing** | **Base (R'000)** | **Year 1 (R'000)** | **Year 2 (R'000)** | **Year 3 (R'000)** | **Year 4 (R'000)** | **Year 5 (R'000)** |
|---|---|---|---|---|---|---|
| Depreciation | R 3 203 | R 641 | R 641 | R 641 | R 641 | R 641 |
| Spend cube operating cost total | R -2 660 | R -2 660 | R -2 773 | R -2 892 | R -3 015 | R -3 144 |
| Total incremental EBIT | | R 2 019 | R 2 133 | R 2 251 | R 2 375 | R 2 504 |
| Tax implication on additional savings | 28% | R 745 | R 777 | R 810 | R 844 | R 880 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -359 | R -179 | R -179 | R -179 | R -179 |
| Incremental NOPAT | | R 1 633 | R 1 536 | R 1 621 | R 1 710 | R 1 803 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 641 | R 641 | R 641 | R 641 | R 641 |
| Incremental cash flow | R -3 203 | R 2 274 | R 2 176 | R 2 262 | R 2 350 | R 2 443 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -3 203 | R 2 274 | R 2 176 | R 2 262 | R 2 350 | R 2 443 |
| Cumulative cash flows | R -3 203 | R -929 | R 1 247 | R 3 509 | R 5 859 | R 8 302 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -3 203 | R 1 995 | R 1 675 | R 1 526 | R 1 392 | R 1 269 |
| WACC | 14% | | | | | |
| NPV | R 4 653 | | | | | |
| Payback period | < 2 years | | | | | |
| 10 years IRR | 65% | | | | | |
| Annual ROI (initial investment) | | 71% | 68% | 71% | 73% | 76% |

Table A9 TCO analysis of Factory 4 using TIJ printing on corrugates

| **Factory 4 End of Line Printing** | **Base (R'000)** | **Year 1 (R'000)** | **Year 2 (R'000)** | **Year 3 (R'000)** | **Year 4 (R'000)** | **Year 5 (R'000)** |
|---|---|---|---|---|---|---|
| Depreciation | R 5 485 | R 1 097 | R 1 097 | R 1 097 | R 1 097 | R 1 097 |
| Spend cube operating cost total | R -2 723 | R -2 723 | R -2 840 | R -2 961 | R -3 087 | R -3 219 |
| Total incremental EBIT | | R 1 626 | R 1 743 | R 1 864 | R 1 990 | R 2 122 |
| Tax implication on additional savings | 28% | R 763 | R 795 | R 829 | R 864 | R 901 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -614 | R -307 | R -307 | R -307 | R - |
| Incremental NOPAT | | R 1 478 | R 1 255 | R 1 342 | R 1 433 | R 1 221 |
| Incremental working capital | R - | R - | R - | R - | R - | R - |
| Add back depreciation | | R 1 097 | R 1 097 | R 1 097 | R 1 097 | R 1 097 |
| Incremental cash flow | R -5 485 | R 2 575 | R 2 352 | R 2 439 | R 2 530 | R 2 318 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -5 485 | R 2 575 | R 2 352 | R 2 439 | R 2 530 | R 2 318 |
| Cumulative cash flows | R -5 485 | R -2 910 | R -558 | R 1 881 | R 4 411 | R 6 728 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -5 485 | R 2 259 | R 1 810 | R 1 646 | R 1 498 | R 1 204 |
| WACC | 14% | | | | | |
| NPV | R 2 931 | | | | | |
| Payback period | < 3 years | | | | | |
| 10 years IRR | 35% | | | | | |
| Annual ROI (initial investment) | | 47% | 43% | 44% | 46% | 42% |

Table A10 TCO analysis of Factory 5 using TIJ printing on corrugates

| Factory 5 End of Line Printing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 1 953 | R 391 | R 391 | R 391 | R 391 | R 391 |
| Spend cube operating cost total | R -1 239 | R -1 239 | R -1 292 | R -1 347 | R -1 404 | R -1 464 |
| Total incremental EBIT | | R 848 | R 901 | R 956 | R 1 014 | R 1 074 |
| Tax implication on additional savings | 28% | R 347 | R 362 | R 377 | R 393 | R 410 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -219 | R -109 | R -109 | R -109 | R - |
| Incremental NOPAT | | R 720 | R 649 | R 688 | R 730 | R 664 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 391 | R 391 | R 391 | R 391 | R 391 |
| Incremental cash flow | R -1 953 | R 1 111 | R 1 039 | R 1 079 | R 1 121 | R 1 054 |
| PV of future cash flows - 10 years | | | | | | |
| Incremental cash flow | R -1 953 | R 1 111 | R 1 039 | R 1 079 | R 1 121 | R 1 054 |
| Cumulative cash flows | R -1 953 | R -843 | R 197 | R 1 276 | R 2 396 | R 3 451 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -1 953 | R 974 | R 800 | R 728 | R 663 | R 548 |
| WACC | 14% | | | | | |
| NPV | R 1 760 | | | | | |
| Payback period | < 3 years | | | | | |
| 10 years IRR | 48% | | | | | |
| Annual ROI (initial investment) | | 57% | 53% | 55% | 57% | 54% |

## APPENDIX B CARTON AND FLEXIBLES TOTAL COST OF OWNERSHIP

Table B1 Number of TIJ printers required for Company 1's flexible packaging format

| Factory | Quantity of Flow Wrapper Coders Required per Factory | Flow Wrapper Cost | Total Cost |
|---|---|---|---|
| Factory 1 | 21 | EUR 7 925.08 | EUR 166 426.68 |
| Factory 2 | 16 | EUR 7 925.08 | EUR 126 801.28 |
| Factory 3 | 14 | EUR 7 925.08 | EUR 110 951.12 |
| Factory 4 | 20 | EUR 7 925.08 | EUR 158 501.60 |
| Factory 5 | 37 | EUR 7 925.08 | EUR 293 227.96 |

Table B2 Estimated TIJ cost per print for Company 1's flexible packaging format

| Factory | Number of Prints Per Flow Wrapper Cartridge | Flow Wrapper Cartridge Cost | Cost Per Print |
|---|---|---|---|
| Factory 1 | 281 525 | R 1 191.35 | R 0.0042 |
| Factory 2 | 281 525 | R 1 191.35 | R 0.0042 |
| Factory 3 | 281 525 | R 1 191.35 | R 0.0042 |
| Factory 4 | 281 525 | R 1 191.35 | R 0.0042 |
| Factory 5 | 281 525 | R 1 191.35 | R 0.0042 |

Table B3 Capex costs of TIJ printing technology on flexibles at Company 1

| Cost Type | Cost Component | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| Capex | TIJ equipment proposal | € 166 427 | € 126 801 | € 110 951 | € 158 502 | € 293 228 |
| | Rate of exchange (ROE) | R 16.50 | R 16.50 | R 16.50 | R 16.50 | R 16.50 |
| | | R 2 746 040 | R 2 092 221 | R 1 830 693 | R 2 615 276 | R 4 838 261 |
| | **Amortisation per annum** | **R 549 208.04** | **R 418 444** | **R 366 139** | **R 523 055** | **R 967 652** |

Table B4 Opex costs of TIJ printing technology on flexibles at Company 1

| Cost Type | Cost Component | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| Opex | Estimated cost per print | R 0.004 | R 0.004 | R 0.004 | R 0.004 | R 0.004 |
| | Annual number of flow wrapper prints | 106 022 780 | 180 401 542 | 199 119 548 | 156 713 561 | 270 223 458 |
| **Total opex cost per annum excluding depreciation** | | **R 448 664** | **R 763 418** | **R 842 629** | **R 663 176** | **R 1 143 524** |
| **Total opex cost per annum including depreciation** | | **R 997 872** | **R 1 181 863** | **R 1 208 767** | **R 1 186 232** | **R 2 111 177** |

Table B5 Number of TIJ printers required for Company 1's carton packaging format

| Factory | Quantity of Carton Coders Required per Factory | Carton Coder Cost | Total Cost |
|---|---|---|---|
| Factory 1 | 13 | EUR 6 539.88 | EUR 85 018.44 |
| Factory 2 | 14 | EUR 6 539.88 | EUR 91 558.32 |
| Factory 3 | 6 | EUR 6 539.88 | EUR 39 239.28 |
| Factory 4 | 8 | EUR 6 539.88 | EUR 52 319.04 |
| Factory 5 | 0 | EUR 6 539.88 | EUR - |

Table B6 Estimated TIJ cost per print for Company 1's carton packaging format

| Factory | Number of Prints per Carton Cartridge | Carton Cartridge Cost | Cost per Print |
|---|---|---|---|
| Factory 1 | 245 525 | R 839.09 | R 0.0034 |
| Factory 2 | 245 525 | R 839.09 | R 0.0034 |
| Factory 3 | 245 525 | R 839.09 | R 0.0034 |
| Factory 4 | 245 525 | R 839.09 | R 0.0034 |
| Factory 5 | 245 525 | R 839.09 | R 0.0034 |

Table B7 Carton capex costs of TIJ printing technology at Company 1

| Cost Type | Cost Component | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| Capex | TIJ Equipment Proposal | € 85 018 | € 91 558 | € 39 239 | € 52 319 | € 0 |
| | Rate of exchange (ROE) | R 16.50 | R 16.50 | R 16.50 | R 16.50 | R 16.50 |
| | | R 1 402 804 | R 1 510 712 | R 647 448 | R 863 264 | R - |
| | **Amortisation per annum** | **R 280 561** | **R 302 142** | **R 129 490** | **R 172 653** | **R -** |

Table B8 Carton opex costs of TIJ printing technology at Company 1

| Cost Type | Cost Component | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| | Estimated cost per print | R 0.0034 | R 0.0034 | R 0.0034 | R 0.0034 | R 0.0034 |
| | Annual number of carton prints | 46 608 878 | 91 380 183 | 58 542 265 | 41 468 071 | 581 646 |
| **Total opex cost per annum excluding depreciation** | | **R 159 287** | **R 312 295** | **R 200 070** | **R 141 719** | **R 1 988** |

| | | | | | |
|---|---|---|---|---|---|
| **Total opex cost per annum including depreciation** | **R 439 848** | **R 614 437** | **R 329 560** | **R 314 371** | **R 1 988** |

Table B9 Opex cost of current flexible and carton printing technology at Company 1

| Cost Type | Spend Cube Cost Components | Factory 1 | Factory 2 | Factory 3 | Factory 4 | Factory 5 |
|---|---|---|---|---|---|---|
| Opex | Print technicians | R - | R - | R - | R - | R - |
| | Continuous ink jet labels | R 78 831 | R - | R - | R - | R - |
| | Continuous ink jet solvents | R 33 402 | R 54 134 | | R 504 939 | |
| | Thermal transfer ribbon | R 366 630 | R 91 930 | R 1 025 658 | R 66 000 | R 740 468 |
| | Repairs and maintenance | R 227 377 | R 372 433 | R 81 484 | R 493 291 | R 68 709 |
| | Parts (printhead) | R 35 015 | | R 230 681 | R 25 060 | R 98 330 |
| | Support and call out | | | | | |
| | Other | R 204 139 | R 374 251 | R 193 093 | R 331 881 | R 139 721 |
| | **Total** | **R 945 394** | **R 892 748** | **R 1 530 916** | **R 1 421 171** | **R 1 047 228** |

Table B10 TCO analysis of Factory 1 using TIJ printing on cartons and flexibles

| Factory 1 Wrapper and Carton Pricing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 4 149 | R 830 | R 830 | R 830 | R 830 | R 830 |
| Spend cube operating cost total | R -945 | R -945 | R -993 | R -1 042 | R -1 094 | R -1 149 |
| Total incremental EBIT | | R 116 | R 163 | R 213 | R 265 | R 319 |
| Tax implication on additional savings | 28% | R 265 | R 278 | R 292 | R 306 | R 322 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -465 | R -232 | R -232 | R -232 | R - |
| Incremental NOPAT | | R 316 | R 117 | R 153 | R 191 | R -2 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 830 | R 830 | R 830 | R 830 | R 830 |
| Incremental cash flow | R -4 149 | R 1 145 | R 947 | R 983 | R 1 020 | R 827 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -4 149 | R 1 145 | R 947 | R 983 | R 1 020 | R 827 |
| Cumulative cash flows | R -4 149 | R -3 003 | R 2 092 | R 1 930 | R 2 003 | R 1 848 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -4 149 | R 1 005 | R 729 | R 663 | R 604 | R 430 |
| WACC | 14% | | | | | |
| NPV | R -718 | | | | | |
| Payback period | < 6 years | | | | | |
| 10 years IRR | 6% | | | | | |
| Annual ROI (initial investment) | | 28% | 23% | 24% | 25% | 20% |

Table B11 TCO analysis of Factory 2 using TIJ printing on cartons and flexibles

| Factory 2 Wrapper and Carton Pricing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 1 831 | R 373 | R 373 | R 373 | R 373 | R 373 |
| Spend cube operating cost total | R -1 531 | R -1 531 | R -1 607 | R -1 688 | R -1 772 | R -1 861 |
| Total incremental EBIT | | R 1 158 | R 1 234 | R 1 314 | R 1 399 | R 1 487 |
| Tax implication on additional savings | 28% | R 429 | R 450 | R 473 | R 496 | R 521 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -209 | R -105 | R -105 | R -105 | R - |
| Incremental NOPAT | | R 938 | R 889 | R 946 | R 1 007 | R 966 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 373 | R 373 | R 373 | R 373 | R 373 |
| Incremental cash flow | R -1 831 | R 1 311 | R 1 262 | R 1 320 | R 1 381 | R 1 340 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -1 831 | R 1 311 | R 1 262 | R 1 320 | R 1 381 | R 1 340 |
| Cumulative cash flows | R -1 831 | R -519 | R 2 573 | R 2 582 | R 2 700 | R 2 720 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -1 831 | R 1 150 | R 971 | R 891 | R 817 | R 696 |
| WACC | 14% | | | | | |
| NPV | R 2 695 | | | | | |
| Payback period | < 4 years | | | | | |
| 10 years IRR | 66% | | | | | |
| Annual ROI (initial investment) | | 70% | 68% | 71% | 74% | 72% |

Table B12 TCO analysis of Factory 3 using TIJ printing on cartons and flexibles

| Factory 3 Wrapper and Carton Pricing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 2 478 | R 496 | R 496 | R 496 | R 496 | R 496 |
| Spend cube operating cost total | R -1 531 | R -1 531 | R -1 607 | R -1 688 | R -1 772 | R -1 861 |
| Total incremental EBIT | | R 1 035 | R 1 112 | R 1 192 | R 1 277 | R 1 365 |
| Tax implication on additional savings | 28% | R 429 | R 450 | R 473 | R 496 | R 521 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -278 | R -139 | R -139 | R -139 | R - |
| Incremental NOPAT | | R 884 | R 801 | R 858 | R 919 | R 844 |
| Incremental working capital | | R - | R - | R - | R - | R - |
| Add back depreciation | | R 496 | R 496 | R 496 | R 496 | R 496 |
| Incremental cash flow | R -2 478 | R 1 380 | R 1 296 | R 1 354 | R 1 415 | R 1 340 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -2 478 | R 1 380 | R 1 296 | R 1 354 | R 1 415 | R 1 340 |
| Cumulative cash flows | R -2 478 | R -1 098 | R 2 676 | R 2 650 | R 2 769 | R 2 755 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -2 478 | R 1 210 | R 997 | R 914 | R 838 | R 696 |
| WACC | 14% | | | | | |
| NPV | R 2 177 | | | | | |
| Payback period | < 3 years | | | | | |
| 10 years IRR | 47% | | | | | |
| Annual ROI (initial investment) | | 56% | 52% | 55% | 57% | 54% |

Table B13 TCO analysis of Factory 4 using TIJ printing on cartons and flexibles

| Factory 4 Wrapper and Carton Pricing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 3 479 | R 696 | R 696 | R 696 | R 696 | R 696 |
| Spend cube operating cost total | R -1 421 | R -1 421 | R -1 492 | R -1 567 | R -1 645 | R -1 727 |
| Total incremental EBIT | | R 725 | R 797 | R 871 | R 949 | R 1 032 |
| Tax implication on additional savings | 28% | R 398 | R 418 | R 439 | R 461 | R 484 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -390 | R -195 | R -195 | R -195 | R - |
| Incremental NOPAT | | R 717 | R 573 | R 627 | R 684 | R 548 |
| Incremental working capital | R - | R - | R - | R - | R - | R - |
| Add back depreciation | | R 696 | R 696 | R 696 | R 696 | R 696 |
| Incremental cash flow | R -3 479 | R 1 413 | R 1 269 | R 1 323 | R 1 379 | R 1 244 |
| PV of future cash flows - 10 years | R - | R - | R - | R - | R - | R - |
| Incremental cash flow | R -3 479 | R 1 413 | R 1 269 | R 1 323 | R 1 379 | R 1 244 |
| Cumulative cash flows | R -3 479 | R -2 066 | R 2 682 | R 2 592 | R 2 702 | R 2 623 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -3 479 | R 1 239 | R 977 | R 893 | R 817 | R 646 |
| WACC | 14% | | | | | |
| NPV | R 1 093 | | | | | |
| Payback period | < 3 years | | | | | |
| 10 years IRR | 27% | | | | | |
| Annual ROI (initial investment) | | 41% | 36% | 38% | 40% | 36% |

Table B14 TCO analysis of Factory 5 using TIJ printing on cartons and flexibles

| Factory 5 Wrapper and Carton Pricing | Base (R'000) | Year 1 (R'000) | Year 2 (R'000) | Year 3 (R'000) | Year 4 (R'000) | Year 5 (R'000) |
|---|---|---|---|---|---|---|
| Depreciation | R 4 838 | R 968 | R 968 | R 968 | R 968 | R 968 |
| Spend cube operating cost total | R -1 047 | R -1 047 | R -1 100 | R -1 155 | R -1 212 | R -1 273 |
| Total incremental EBIT | | R 80 | R 132 | R 187 | R 245 | R 305 |
| Tax implication on additional savings | 28% | R 293 | R 308 | R 323 | R 339 | R 356 |
| Tax allowance S12C on machinery | 40:20:20:20 | R -542 | R -271 | R -271 | R -271 | R - |
| Incremental NOPAT | | R 328 | R 95 | R 135 | R 176 | R -51 |
| Incremental working capital | R - | R - | R - | R - | R - | R - |
| Add back depreciation | | R 968 | R 968 | R 968 | R 968 | R 968 |
| Incremental cash flow | R -4 838 | R 1 296 | R 1 063 | R 1 102 | R 1 144 | R 916 |
| PV of future cash flows - 10 years | | | | | | |
| Incremental cash flow | R -4 838 | R 1 296 | R 1 063 | R 1 102 | R 1 144 | R 916 |
| Cumulative cash flows | R -4 838 | R -3 542 | R 2 359 | R 2 165 | R 2 246 | R 2 060 |
| Discount factor | 1.0 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |
| Discounted cash flow | R -4 838 | R 1 137 | R 818 | R 744 | R 677 | R 476 |
| WACC | 14% | | | | | |
| NPV | R -987 | | | | | |
| Payback period | < 7 years | | | | | |
| 10 years IRR | 5% | | | | | |
| Annual ROI (initial investment) | | 27% | 22% | 23% | 24% | 19% |

## APPENDIX C SURVEY MONKEY QUESTIONNAIRE

**Instructions to Company 1 Employees Participating in the Online Questionnaire**

1. The table below summarises the various coding and marking technologies used today.
2. Some of these technologies (like continuous ink jet, thermal transfer overprinting and thermal ink jet) are currently in use, while others (like laser coding and micro piezo) are not.
3. Thermal ink jet technology has only recently been introduced, whereas continuous ink jet and thermal transfer overprinting have been in use longer.
4. The purpose of these technologies includes marking of the best before date and manufacturing date on the carton and flexible packaging.
5. Furthermore they are also responsible for the marking of barcodes onto white labels, which are then applied onto corrugates using a technology called print-and-apply.
6. Print-and-apply technology is not shown in the table below but this is identical to thermal transfer overprinting, except that printing occurs on white labels, rather than on flexible film.
7. Also not mention below is micro piezo technology which is capable of printing high quality images on corrugates using less ink than thermal ink jet technology.

Table C1 Summary of the various coding and marking technologies used today

| Technology | Consumables | Works on Flexibles only | Works on any Substrate | Green Technology | Maintenance Required | High Print Quality | Print-Head Contact Technology |
|---|---|---|---|---|---|---|---|
| Continuous ink jet | Ink + solvent | No | Yes | No | Yes | No | No |
| Thermal transfer overprinting | Ribbon | Yes | No | Yes | Yes | Yes | Yes |
| Thermal ink jet | Ink cartridge | No | Yes | Yes | No | Yes | No |
| Laser coding | None | No | Yes | No | Yes | Yes | No |

**Survey Monkey Questions**

Question 1: Please indicate the department in which you currently work?

Question 2: Please indicate which factory you currently work at, or if you are based at National Brands Limited head office?

Question 3: Please indicate the coding and marking technologies currently in use at the factory where you work? You may select more than one answer.

Question 4: The best before date and manufacturing date, are printed on the flexible packaging, or primary packaging concealing the product. If cartons are also being used to package the product, then this is printed onto the cartons too, or secondary packaging, in a designated area that typically does not contain varnish. Why do you think this requirement is necessary? You may select more than one answer.

Question 5: Can you specify the main packaging formats in use at the factory where you work at? You may select more than one answer.

Question 6: Are you aware of the associated risks with continuous ink jet technology? You may select more than one answer.

Question 7: Which coding and marking technology is best suited for the packaging format at the factory where you work? If you are based at head office, please base your answer on the whole of Company 1?

Question 8: The only consumable with thermal ink jet printing, is an ink cartridge which requires replacement once empty. How long do you think it would take the line operator to replace the ink cartridge?

Question 9: Which monthly key performance indicators are critical to measuring the performance of the respective printing technology used, if the factory were to select thermal ink jet technology on all packaging formats? You may select more than one answer.

Question 10: Which monthly key performance indicators are critical to measuring the performance of the respective printing technology used, if the factory were to select thermal transfer overprinting on the flexible packaging lines? You may select more than one answer.

Question 11: Which monthly key performance indicators are critical to measuring the performance of the respective printing technology used, if the factory were to select continuous ink jet technology all on packaging formats? You may select more than one answer.

Question 12: Why do you think thermal ink jet printing will prove to be a more suitable alternative, to the current printing technology in use at the factory where you work? You may select more than one answer.

Question 13: Thermal ink jet printing of barcode data may be applied directly onto the corrugates without the need for a label. How do you think this will impact the supply chain process? You may select more than one answer.

Question 14: Thermal ink jet printing will also use a standard control system interface, regardless of the packaging format onto which it is printing. How do you think this will affect the operator? You may select more than one answer.

Question 15: Please indicate your desired allocation of printing technologies (for the main packaging formats) currently in use at the factory where you work. If you do not work at any of the factories please select for the whole of Company 1? Please select one technology for each packaging format.

Question 16: Which coding and marking technology has the highest capital outlay (or capex) cost?

Question 17: Which coding or marking technology has the lowest capital outlay (or capex) cost?

Question 18: Please estimate the current total annual operating spend of the printing technology used on the corrugate packaging at the factory where you work? Remember this cost is a print-and-apply application, using a white label sticker with 3 barcodes printed onto the sticker for identification of the batch number, purchase order number and material number.

Question 19: Please estimate the total annual operating spend of the printing technology used on the carton and flexible packaging formats, at the factory where you work?

Question 20: Please estimate the total annual operating spend of the printing technology used on the corrugate packaging format, for all 5 factories at Company 1? Remember this cost is a print-and-apply application, using a white label with 3 barcodes printed onto the label for identification of the batch number, purchase order number and material number.

Question 21: Please estimate the total annual operating cost of the printing technology used on cartons and flexible packaging formats, for all 5 factories at Company 1? This is the cost of printing the best before and manufacturing date.

Question 22: Reliability, availability, maintainability, and safety are also known by the acronym RAMS which is defined below. Please select the coding and marking technology that complies best with the RAMS methodology below:

- Reliability is a product's or system's ability to perform a specific function and may be given as design reliability or operational reliability.
- Availability is the ability of a system to be kept in a functioning state.
- Maintainability is determined by the ease with which the product or system can be repaired or maintained.
- Safety is the requirement not to harm people, the environment, or any other assets during a system's life cycle.

Question 23: Business intelligence can be better monitored with thermal ink jet systems. Examples include integration capabilities to most systems, like SAP, as well as remote log-in to repair any faults where needed. Do you believe this is a critical requirement for a fast moving consumer goods organisation like National Brands Limited? If yes please state why?

Question 24: If Company 1 were to print directly onto their corrugates using thermal ink jet technology, what would be the largest risk to obtaining a readable barcode print?

Question 25: If Company 1 were to use thermal ink jet technology across its 5 factories, what would be the easiest way to save on consumable (or cartridge) costs without compromising on any aspects of the supply chain?

Question 26: The coding and marking equipment for National Brands Limited, fully depreciates over a 5 year period. Which printing technologies would require replacement after 5 years, or possibly sooner? You may select more than one answer.

Question 27: Please select the reason(s) that best explain your response to question 26 above? You may select more than one answer.

Question 28: Which coding or marking technology do you think will last longer than 5 years, before requiring any equipment to be replaced? You may select more than one answer.

Question 29: Please select the reasons that best explain your response to question 28? You may select more than one answer.

## APPENDIX D SURVEY MONKEY QUESTIONNAIRE ANALYSIS

**Feedback on question 1**

The purpose of question 1 was to ensure participation from a diverse range of respondents within Company 1, in order to analyse any potential bias that may arise later on within the survey. Figure D1 below represents the various departments of each of the participants, with R&D having the largest input with 4 participants, followed next by Supply Chain and Logistics with 2 participants for each respectively. IT, Engineering, Marketing, Projects, Finance, Manufacturing and Quality each had 1 participant.

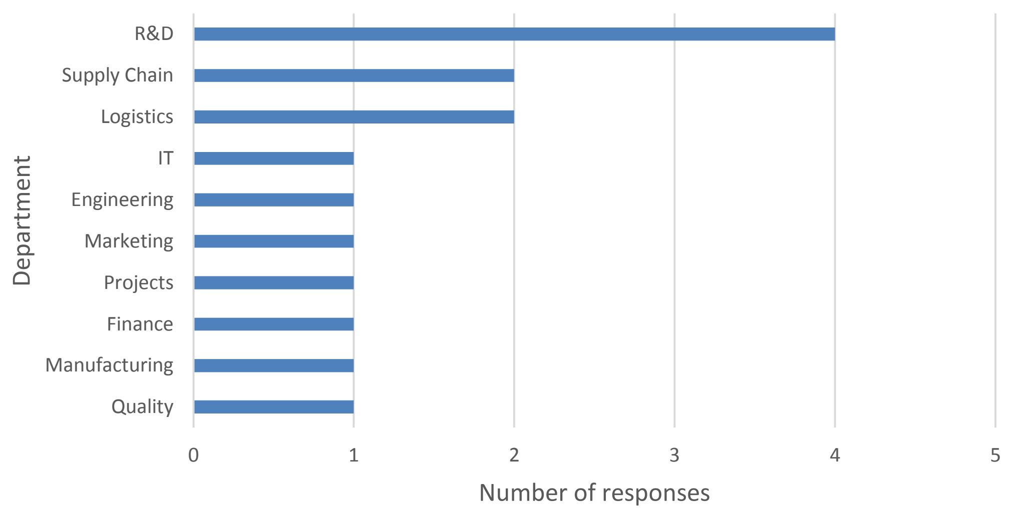


Figure D1 Number of respondents surveyed

**Feedback on question 2**

The location of employment of the largest group of respondents is at the head office of Company 1, as shown in Figure D2, with a total 7 employees confirming this. The next largest response from a factory location perspective, was from Factory 3 with a total of 4 employees taking part in the survey. Furthermore an employee from Factories, 4, 5, and 1 also took part in the survey. There was also one employee from Company 1's IT shared services that took also part in the survey. No employee(s) from Factory 2 opted to take part in the survey. Therefore a spread of employees from various factories was obtained to ensure equal participation as far as possible.

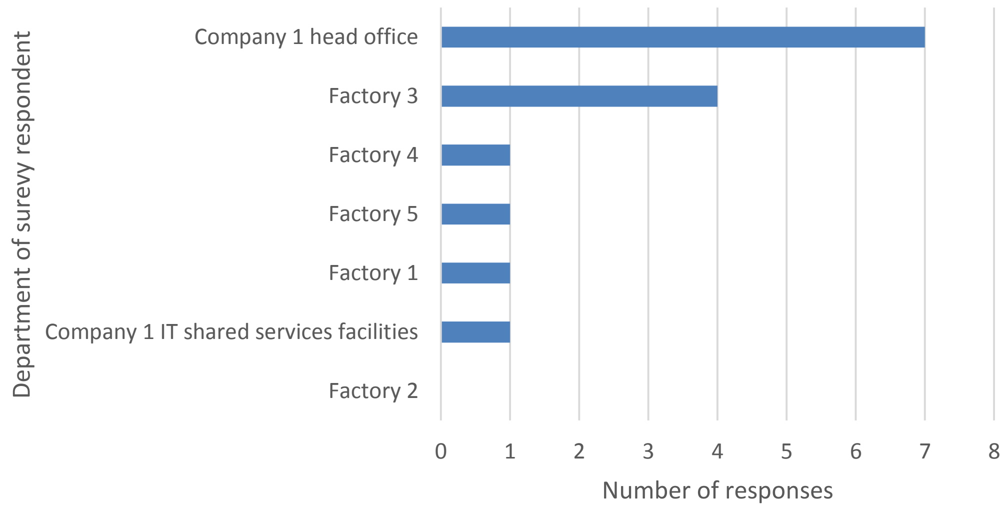


Figure D2 Department of survey respondents

**Feedback on question 3**

The most prevalent technology in use at Company 1 is TTO with a total of 8 responses as shown in Figure D3 below, followed equally by CIJ and print-and-apply technology, which each obtained 7 responses. There were 4 respondents that were not sure on the exact coding and marking technology used, while 3 employees confirmed that TIJ printing was already operational at Company 1, along with 1 response confirming the use of micro piezo technology and laser coding technology respectively.

These results are accurate as TTO, CIJ and print-and-apply technology are the prevalent technologies currently in use at all 5 factories. The only incorrect answer was that of laser coding and micro piezo, however, only one respondent confirmed this.

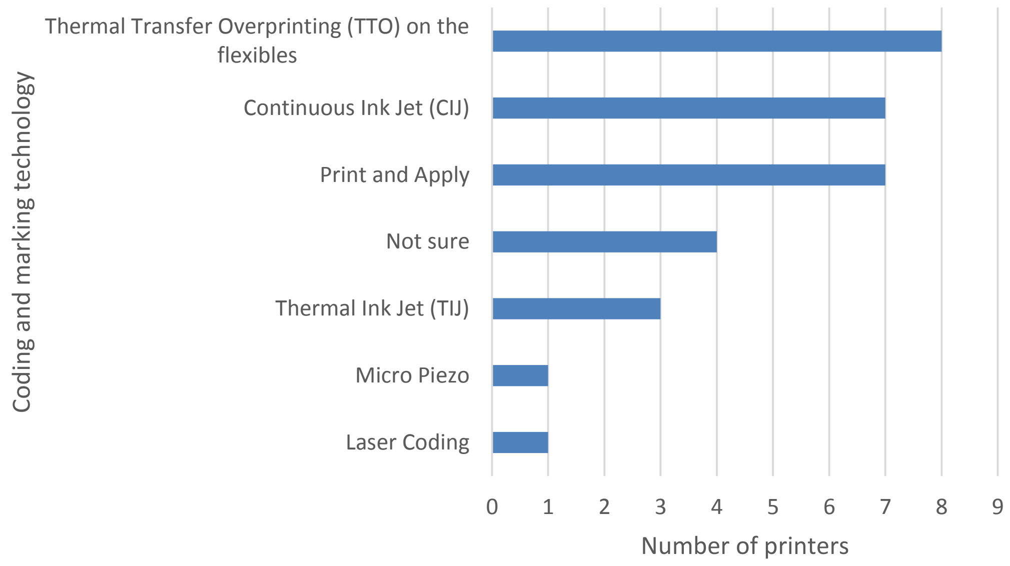


Figure D3 Coding technologies currently in use at Company 1

**Feedback on question 4**

The purpose of question 4 was to test and ensure whether the employee understands that the need for a BB date is a compulsory requirement within the food and beverage industry, with 12 employees confirming this as shown in Figure D4. In addition to the compulsory requirement, another 12 responses confirmed that the BB date and MD assist with traceability and improved control of batch management processes, which are critical in the supply chain.

Lastly, 8 respondents confirmed that the BB date and MD assist with improved management of warehousing and distribution within the supply chain with first-in, first-out (FIFO) principles, or alternatively last-in, first-out principles (LIFO) if required. No employees responded on the option stating that the BB date and MD are not a critical requirement, as the shelf life on most products is long with little to no risk of the product expiring and filtering into the trade. This reinforces that all employees do understand the implication on the supply chain, however it is important to note that 3 respondents did not select option 3 which is a critical requirement.

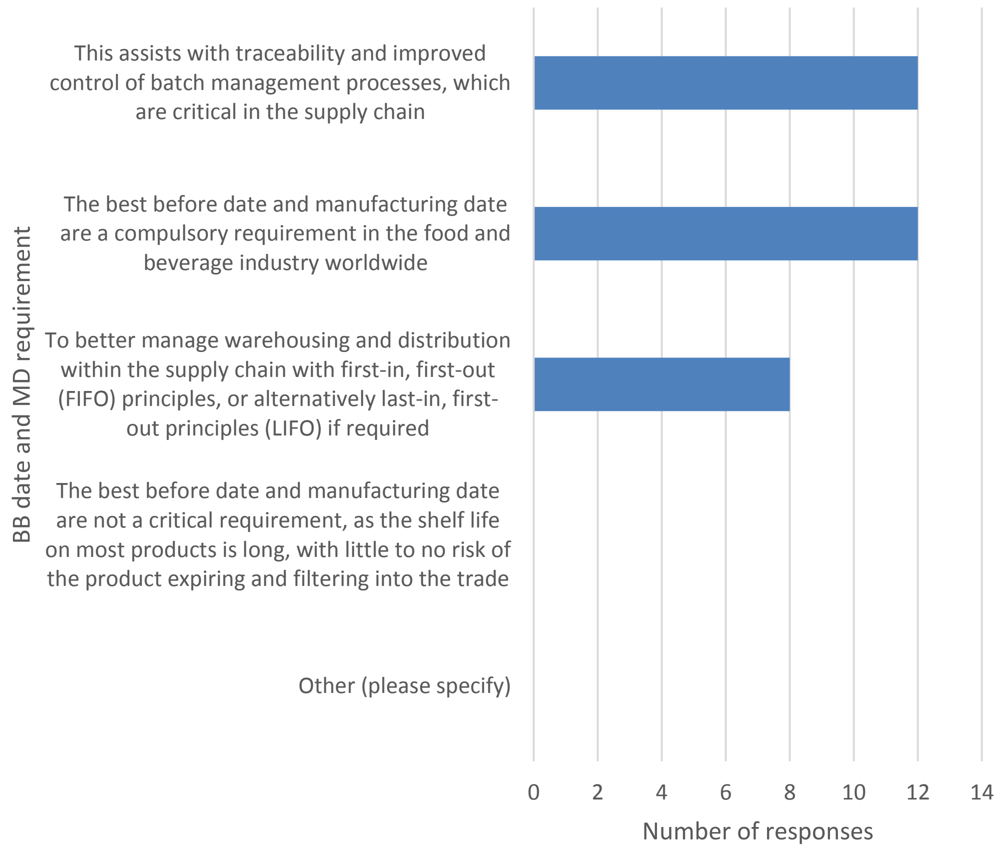


Figure D4 Reasons on why a BB and MD are required

**Feedback on question 5**

The intention of question was to determine if all employees acknowledged that there are 3 main packaging formats currently in use at their factory in which they work. With reference to Figure D5 the respondents did answer correctly, with 13 responses confirming the corrugate format, 12 responses confirming the carton format and 13 responses confirming the flexible format. Factories 1, 2, 3, and 4 utilise all packaging formats, whereas factory 5 utilises the corrugate and flexible format, but not the carton format.

Furthermore 4 respondents from factory acknowledged cans as a fourth packaging format which is correct, but only in use at Factory 1. One respondent replied other since they did not work at any of the factories and hence, thought of shrink wrap as another format.

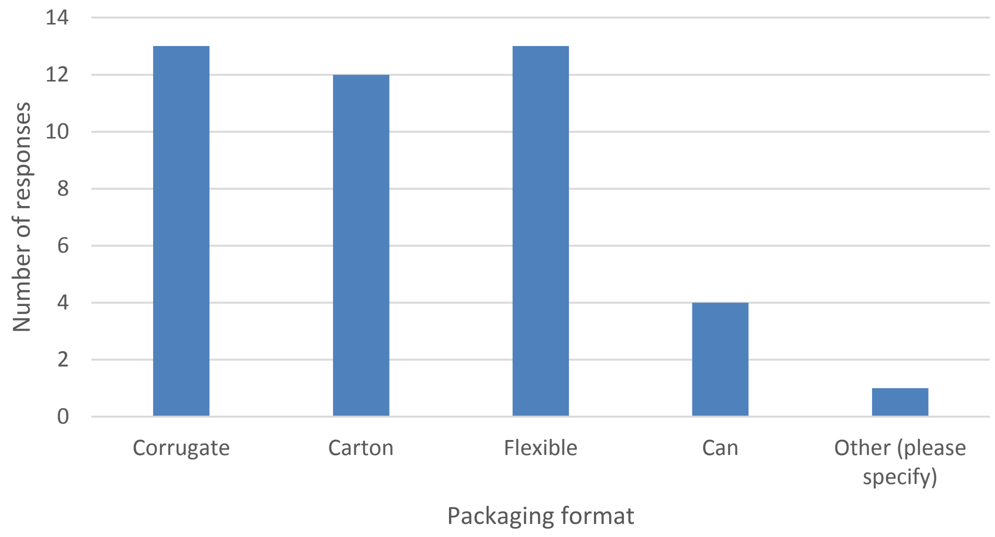


Figure D5 Feedback on the main packaging formats in use at Company 1

**Feedback on question 6**

According to the survey the largest risk with CIJ technology is that the operating cost is high, due to the ongoing maintenance required, with 8 employees confirming this as shown in Figure D6. The second largest risk is that the print quality would be low, making it difficult to obtain class barcodes and 2D codes, with 5 employees confirming this. Similarly, another 5 employees confirmed that some inks are solvent based and contain methyl-ethyl-ketones (MEK), which can be harmful to the user and the environment.

Only 2 employees are of the view that CIJ technology has no risk whatsoever, with another 2 employees confirming that reliability is low when using CIJ technology. One employee selected other and explained that the technology was not easy to be obtained locally, however this is not that case since CIJ technology is the second most prevalent technology at Company 1 after TTO.

Therefore all other responses are correct with the exception of the answer stating there is no risk in using CIJ technology, which obtained 2 responses from head office based respondents.

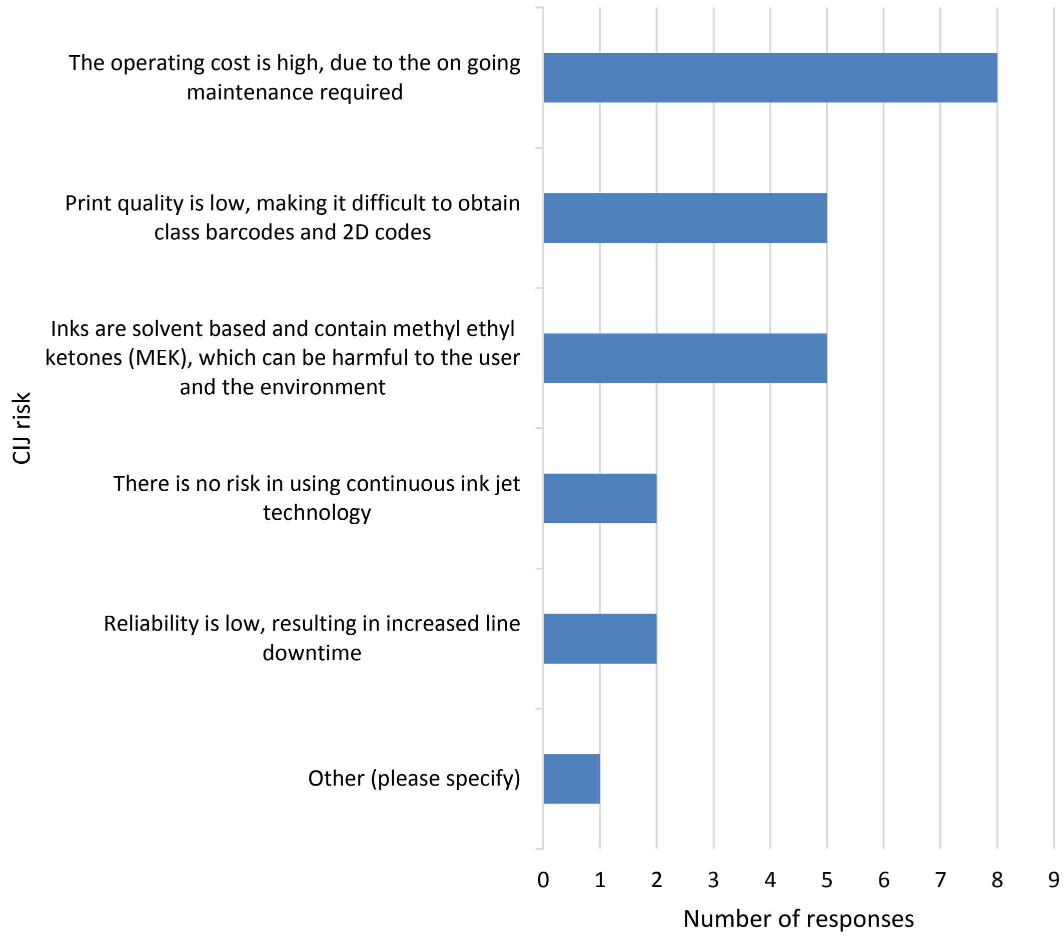


Figure D6 Associated risks in utilising TIJ technology

**Feedback on question 7**

On the corrugate packaging format, 5 employees confirmed that TIJ technology would be the most suitable technology, as shown in Figure D7, making this the highest number of responses for this packaging format On the carton packaging format an equal number of 4 responses were obtained for both CIJ and TIJ technology respectively.

On the flexible packaging format there were also an equal number of responses with 4 employees confirming that CIJ and TTO would be the most suitable technology for this packaging format. Lastly the most suitable technology for the cans packaging format is CIJ technology with 3 employees confirming this.

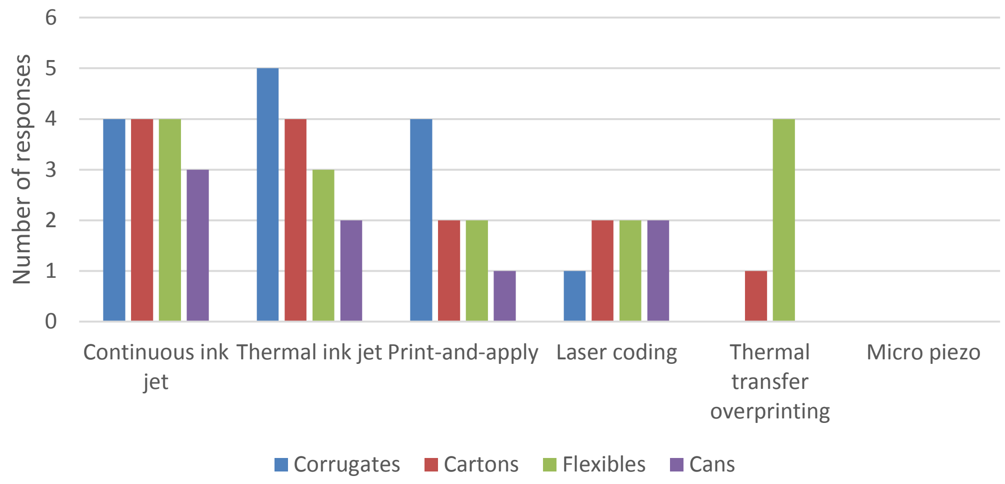


Figure D7 Coding and marking technology best suited for Company 1

**Feedback on question 8**

Most employees responded with a cartridge time change option of greater than one minute, as shown in Figure D8, but less than or equal to 2 minutes, with 5 employees confirming this. Another 3 employees felt that a cartridge change would take less than or equal to 3 minutes. In reality a cartridge change can effectively be done in under 30 seconds according to feedback from Supplier 1, provided inventory of the new cartridge is in close proximity to the TIJ printer.

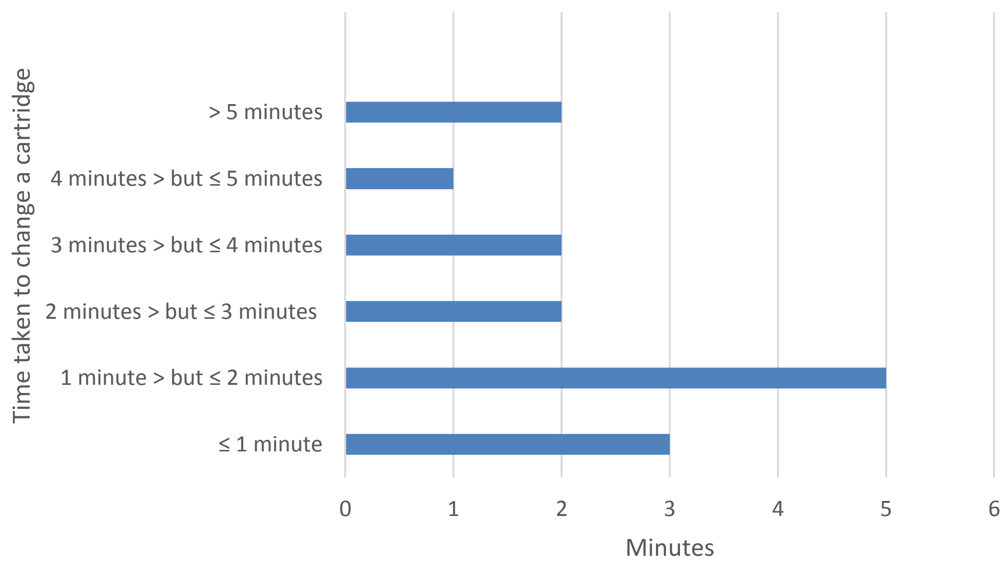


Figure D8 Time taken for the line operator to replace a TIJ ink cartridge

**Feedback on question 9**

The most critical KPIs are shown in Figure D9 and include cartridge costs, line downtime, number of print defects, and operational efficiency with 12, 9, 8 and 7 confirmations respectively. Repairs and support, and number of cartridges used each obtained 6 confirmations, while maintenance costs and labour required each obtained 5 confirmations. Two respondents selected other and explained that they were unsure of which answer to select.

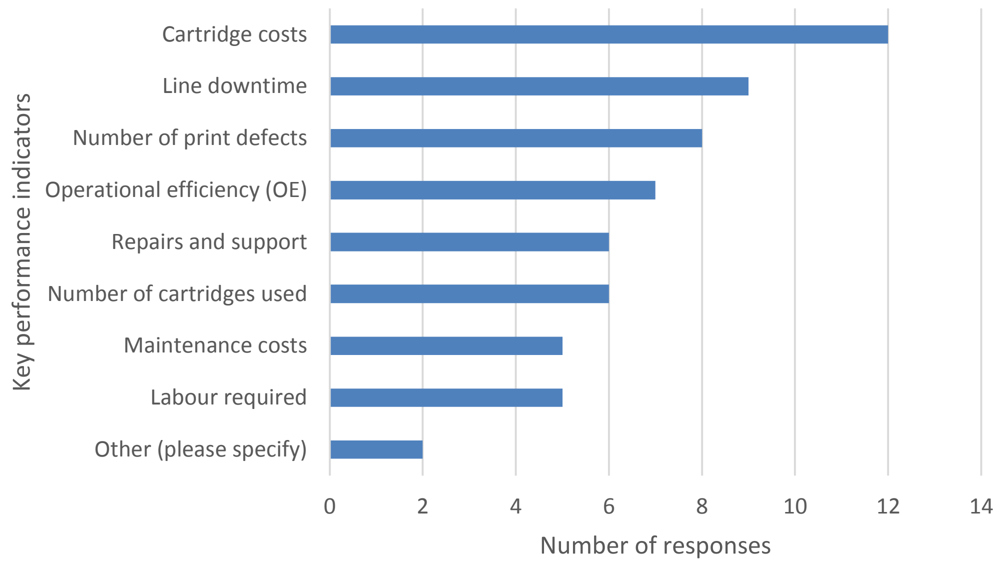


Figure D9 KPIs that are most critical in measuring the performance of TIJ technology

**Feedback on question 10**

Based on Figure D10 the most critical KPIs are ribbon reel length consumption, and repairs and support costs, which together each received 8 responses respectively. The next most critical KPIs are labour usage costs, OE and OU, and ribbon reel costs which each received 7 responses respectively. This was then followed by KPIs that included engineering and spare parts with 3 responses, followed by 1 other confirmation, which the respondent explained they were unsure of.

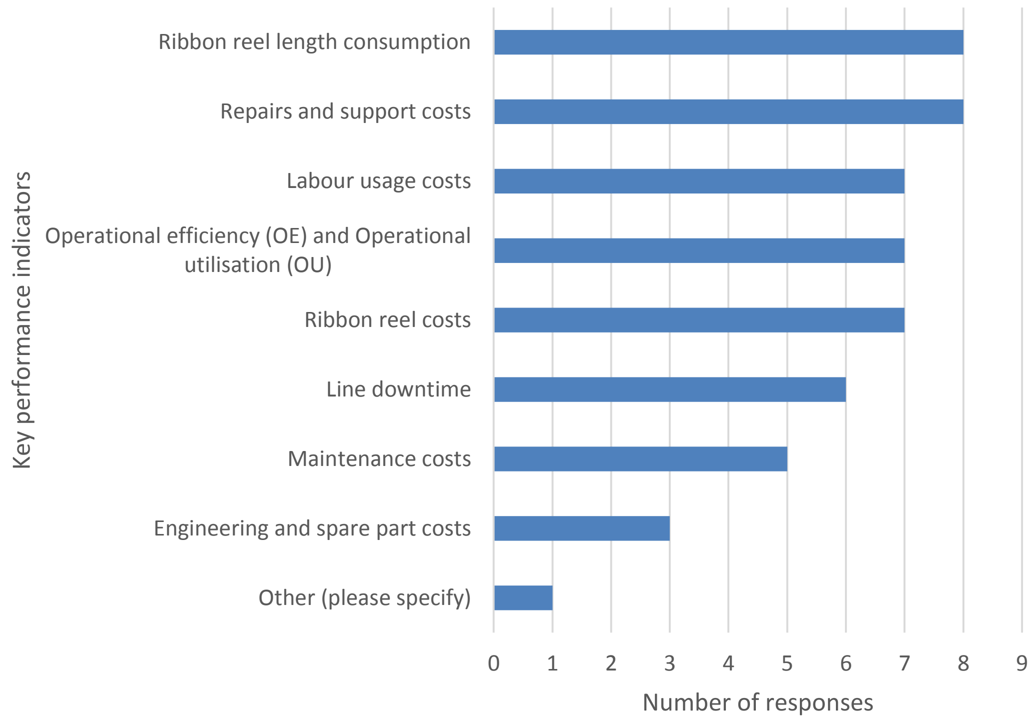


Figure D10 KPIs that are most critical in measuring the performance of TTO

**Feedback on question 11**

Based on the feedback as shown in Figure D11, ink solvent costs and number of print defects were selected as being the most critical KPIs with each receiving 10 responses respectively. The second most critical KPI is line downtime with 9 responses, followed by OEE, and repairs and support costs with 7 responses each. OE and OU, and maintenance costs obtained 6 responses. Engineering and spare parts obtained 3 responses, while 2 participants selected other with reasoning that they did not know what the correct answer is.

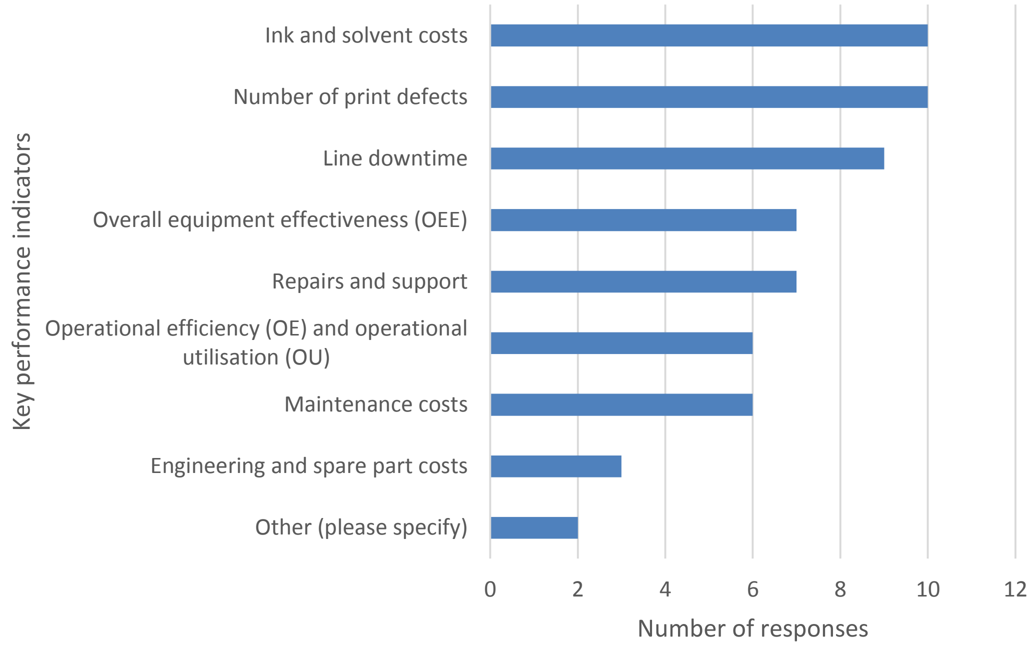


Figure D11 KPIs that are most critical in measuring the performance of CIJ technology

**Feedback on question 12**

The 2 main reasons for TIJ printing being a more suitable alternative to the current printing technologies within Company 1 include there being a lower TCO due to the minimal maintenance requirements (if any), as well as TIJ technology being capable of printing onto nearly any packaging format including corrugates, cartons and flexible film. Each of these reasons received 9 responses respectively as shown in Figure D12. There were also 6 respondents who selected the reason that TIJ technology is more suitable than the current printing technologies at Company 1, is due the technology not containing any moving parts which results in reduced wear-and-tear, maintenance and a longer life-span, when compared to other printing technologies.

A total of 5 responses were obtained for reasons that included the printing technology being capable of a higher DPI allowing for number, text, barcodes and 2D codes. Similarly 5 responses were also obtained for reasons that include TIJ technology being a safer technology for the operator and the environment to the omission of ketones in its ink cartridges. Lastly, another 5 respondents felt that TIJ technology is a better alternative to the current printing technologies used within Company 1, due to it being less complex to operate as there is a general lack of skill on the factory floor.

Furthermore one respondent selected 'other' as a reason confirming that the technology will provide a platform that can allow for an easy migration to micro piezo technology at a later stage on the corrugate packaging format.

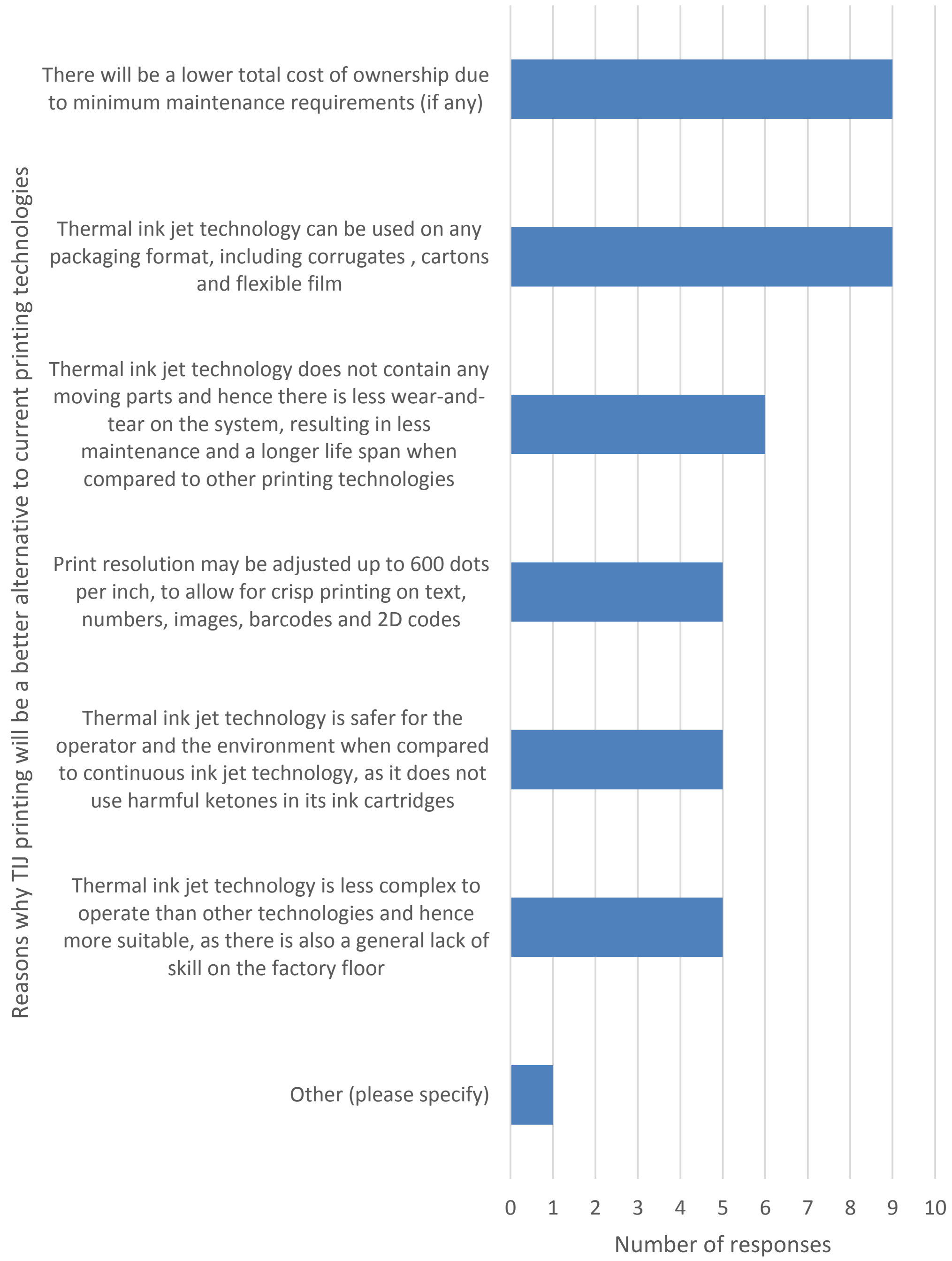


Figure D12 Reasons why TIJ printing will be a better alternative to current printing

**Feedback on question 13**

A total of 12 respondents confirmed that there will no longer be a requirement for labels, which ensures that TIJ printing maintains a better opex cost than the current printing technologies in use at Company 1 as shown in Figure D13, due to TIJ printing directly onto the corrugate packaging format. A total of 7 respondents confirmed that there will be less line downtime and an improved operational efficiency and operational utilisation.

The third largest potential impact on the supply chain includes there no longer being a requirement to have someone permanently monitoring the packaging line to ensure the labels are applied correctly onto the corrugates, with 6 respondents selecting this option. The ‘other’ option was selected as the fourth largest potential impact on the supply chain with all 3 respondents whom selected this option confirming that the process will be significantly improved in terms of operational efficiency.

Only 2 respondents felt that there would be a backlog in rejections if the TIJ printer was not printing barcode data correctly which would result in the operator struggling to maintain control. Similarly 2 respondents confirmed that the warehouse staff would be negatively affected since there would no longer be visibility of the white sticker on the corrugates, which could affect warehouse management processes such as picking efficiency.

Lastly 1 respondent confirmed that the current process which uses a print-and-apply technology to apply a white label sticker directly onto the corrugates is better and more effective than TIJ printing, provided that there is a designated person controlling this process.

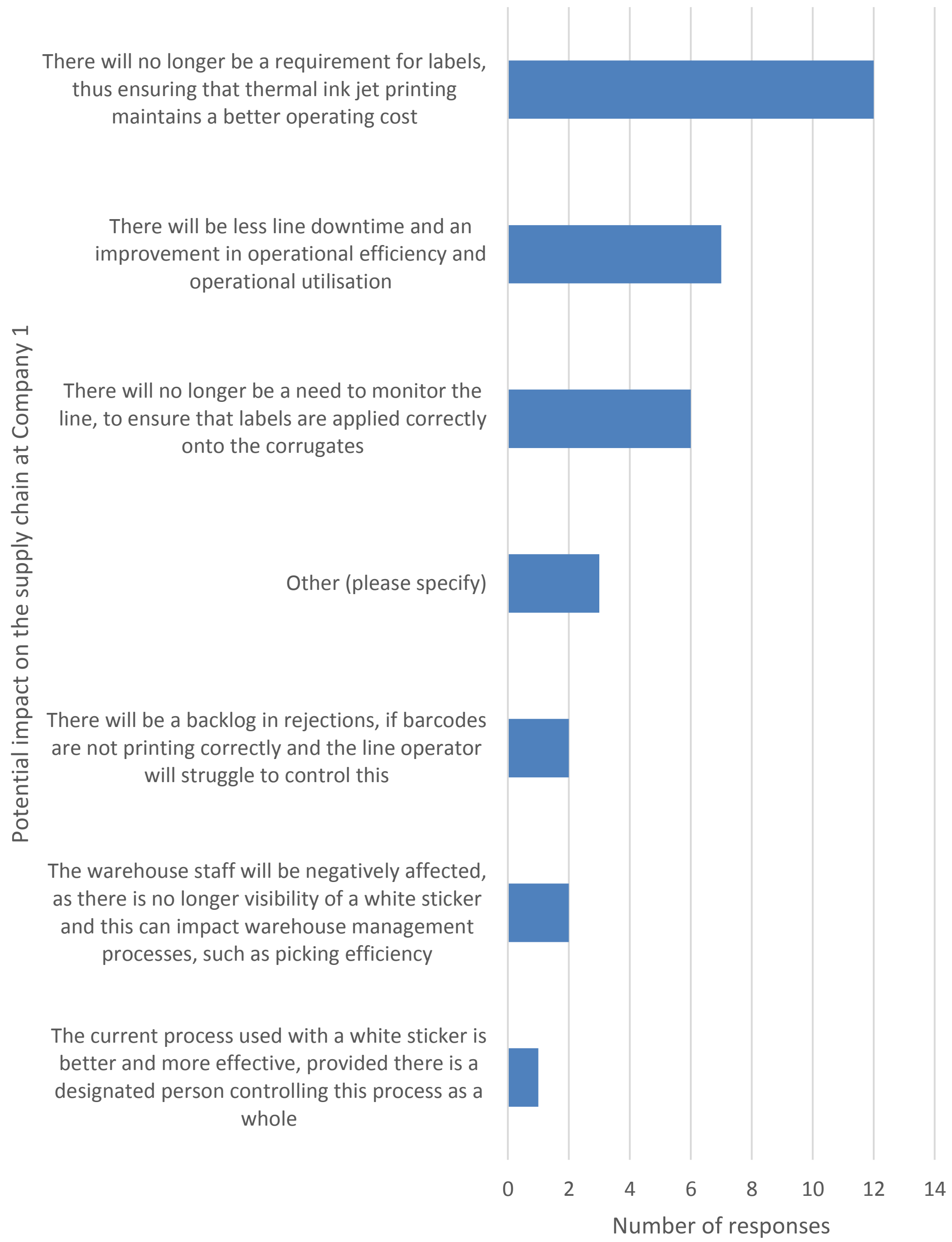


Figure D13 Potential impact on the supply chain at Company 1

**Feedback on question 14**

The greatest benefit of having a standard control system interface is that this will prove more cost-effective in the long term by allowing for interchanging of controllers and hence, a reduction in opex costs as shown in Figure D14 with 12 respondents confirming this. Furthermore, a total of 6 respondents confirmed that a standard control interface should ultimately improve the operational efficiency of the line. Similarly another 6 respondents confirmed that a standard control interface would ensure that the end-user can easily utilise the technology, with a reduction in the need for training and support.

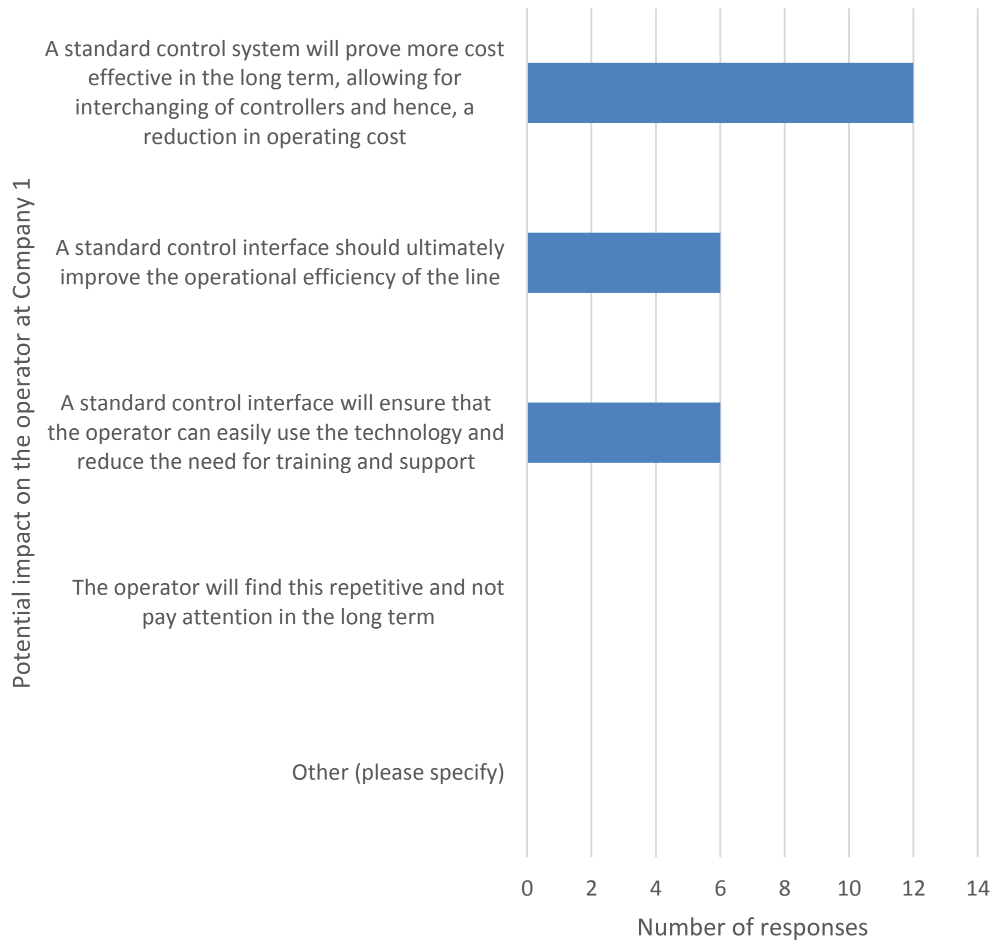


Figure D14 Potential impact on the operator at Company 1

**Feedback on question 15**

The most desired allocation of printing technologies on the corrugate, carton and can packaging format is TIJ technology with a total of 6, 6, and 5 respondents confirming this respectively, as shown in Figure D15. The most suitable printing technology on the flexible packaging format is both TTO and TIJ technology, with each receiving 4 responses respectively.

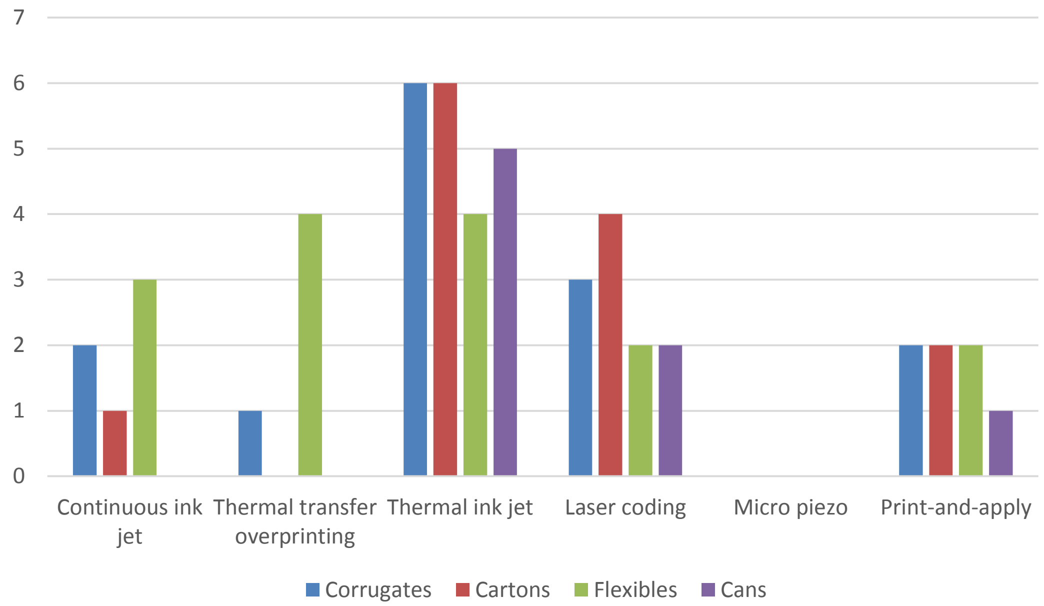


Figure D15 Recommended allocation of printing technologies for Company 1

**Feedback on question 16**

Based on the feedback from the respondents in Figure D16, the perception is that laser coding is the most expensive printing technology from a capex perspective, with 5 respondents confirming this, followed next by micro piezo with 3 confirmed responses and then by CIJ, TIJ and 'other' with 2 responses each respectively. The 2 respondents that selected 'other' further explained that they were unsure which technology would have the highest capex cost.

Only 1 respondent confirmed that print-and apply technology would have the highest capital outlay cost. No respondents believed that TTO would be the most expensive technology from a capital outlay perspective.

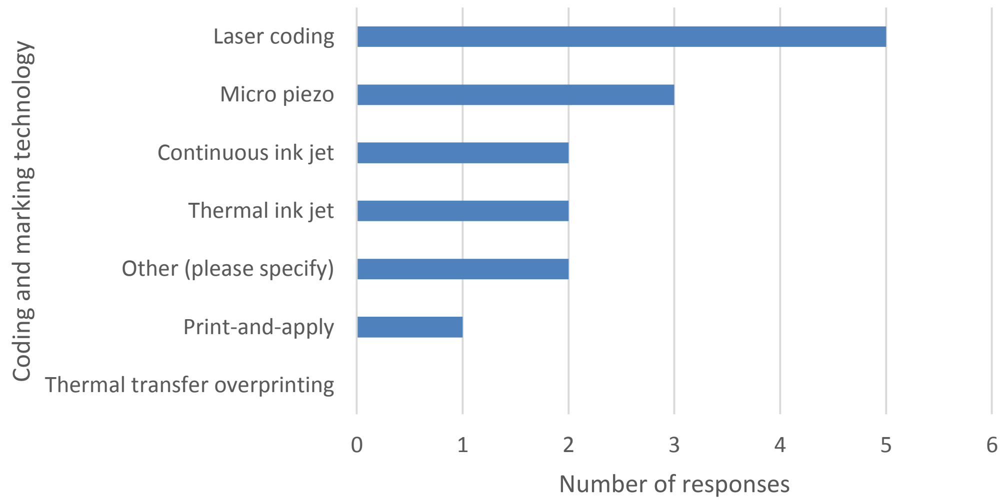


Figure D16 Coding and marking technologies with the highest capital cost

**Feedback on question 17**

Based on the feedback received the majority participants selected print-and-apply technology as having the lowest capex cost, with a total of 5 participants selecting this option as shown in Figure D17. The participants then selected TTO in second place as the printing technology with the lowest capex cost with 3 participants confirming this. CIJ, laser coding and 'other' are all joint in third place, with 2 participants selecting each of these options respectively. TIJ technology came in last with only 1 confirmed response.

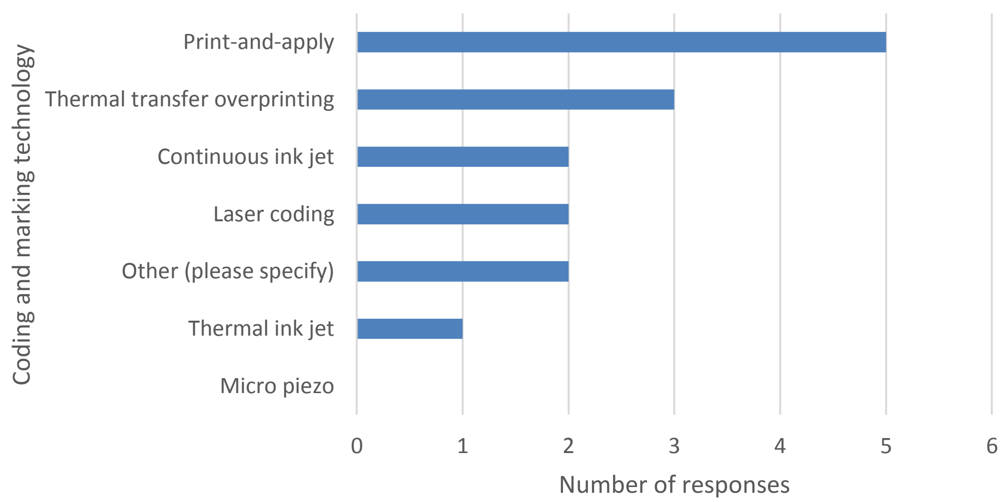


Figure D17 Coding and marking technologies with the lowest capital cost

**Feedback on question 18**

Most participants selected an annual opex cost of the current print-and-apply technology, used on the corrugate packaging format, to be greater than R500 000 but less than R1000 000. A total of 4 confirmed responses were selected for this option as shown in Figure D18, while the next largest response was 3 participants whom selected an annual opex range of greater than R2 500 000 while another 3 respondents selected 'other' with each of these 3 respondents explaining that they were unsure of the annual opex cost. There were 2 respondents that selected an annual opex range of more than R1 000 000 but less than R1 500 000. Similarly another 2 respondents selected an annual opex range of more than R1 500 000 but less than R2 000 000, while only I participant selected an annual opex range of more than R2 000 000 but less than R2 500 000.

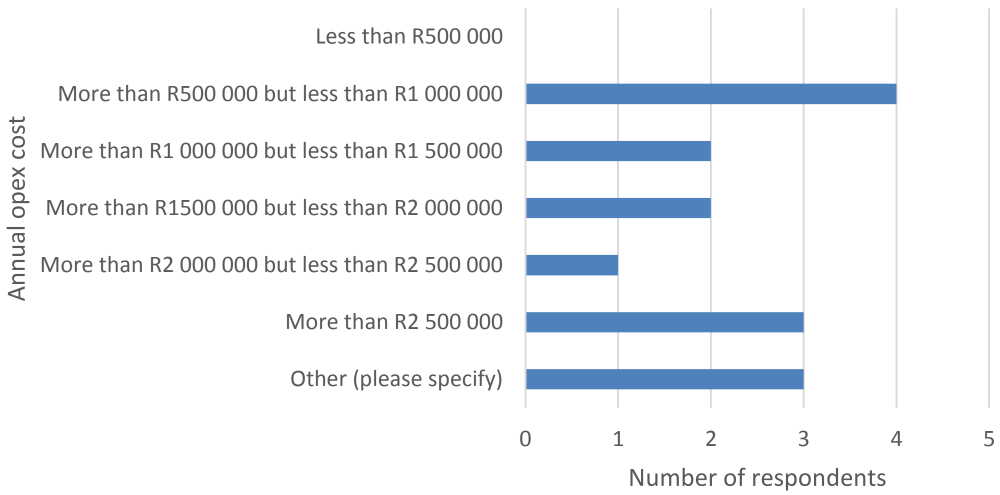


Figure D18 Estimated annual opex cost of print-and-apply technology

**Feedback on question 19**

Most participants selected an annual opex range on the current combined CIJ and TTO technology set-up, used on the carton and flexible packaging formats at Company 1, to be greater than R2 500 000. A total of 4 confirmed responses selected this option as shown in Figure D19, while the next largest responses were 3 participants whom selected an annual opex range of more than R500 000 but less than R1 000 000, while another 3 respondents selected more than R1 000 000 but less than R1 500 000 respectively. Similarly, another 3 participants felt that the annual opex range is more than R2 000 000 but less than R2 500 000, while another 2 respondents selected ‘other’ and further explained that they were unsure on the annual opex range.

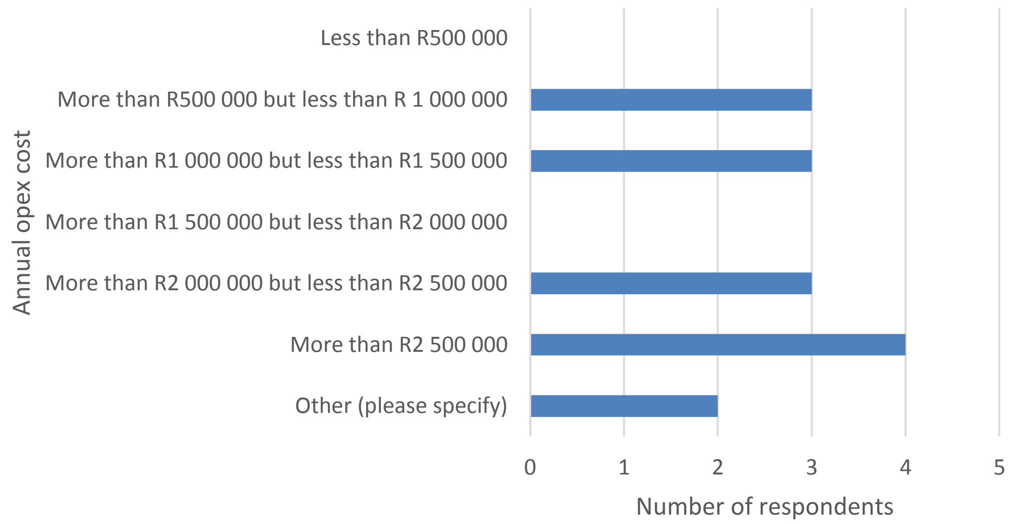


Figure D19 Estimated annual opex cost of current carton and flexible printing

**Feedback on question 20**

The average annual opex cost of the current print-and apply technology being used on the corrugate packaging format is R4 376 923 based on the feedback from 13 participants that responded, while the remaining 2 were not sure.

Based on Figure D20 the lowest annual opex cost was from respondent 4 at R2 500 000, while the largest annual opex response was from respondent 6 at R7 000 000. This therefore equates to a range of:

∴ Annual opex print-and-apply cost range = R7 000 000 – R2 500 000 = R4 500 000

∴ Annual opex print-and-apply cost range = R4 500 000

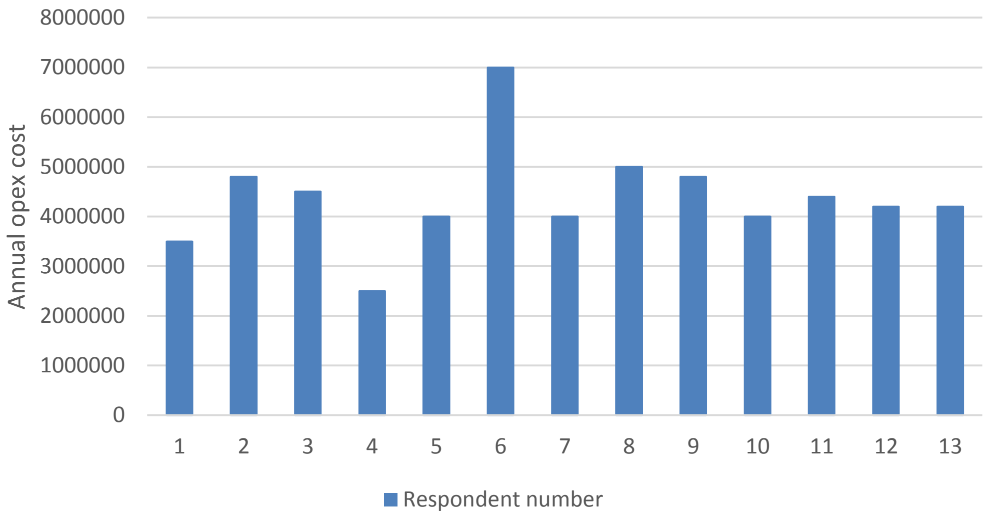


Figure D20 Average annual opex cost on current print-and-apply technology at Company 1

**Feedback on question 21**

The average annual opex cost of the current print-and apply technology being used on the corrugate packaging format is R4 383 333 based on the feedback from 12 participants that responded, while the remaining 3 were not sure. Based on Figure D21, the lowest annual opex cost was from respondent 4 at R2 800 000, while the largest annual opex response was from respondent 6 at R6 000 000. This therefore equates to a range of:

∴ Annual opex print-and-apply cost range = R6 000 000 – R2 800 000 = R3 200 000

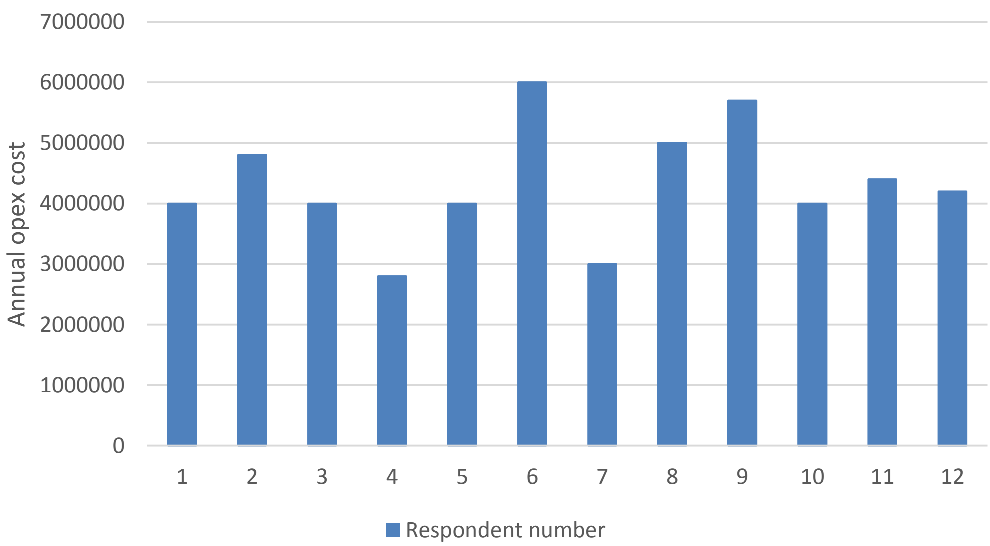


Figure D.21 Average annual opex cost on current TTO and CIJ technology at Company 1

**Feedback on question 22**

Based on the RAMS definition provided to the participants, the largest number of responses as shown in Figure D22 were from 6 participants who felt that both CIJ and TTO technology would provide the highest level of reliability for Company 1 respectively. Similarly, 5 participants felt that the most suitable technology from an availability perspective is also CIJ and TTO technology respectively. TIJ and print-and-apply technology were considered to be the most suitable technologies from a maintainability perspective with each obtaining 4 responses respectively. The most suitable technology from safety perspective is TIJ, micro piezo and print-and-apply technology, with each obtaining 3 responses respectively.

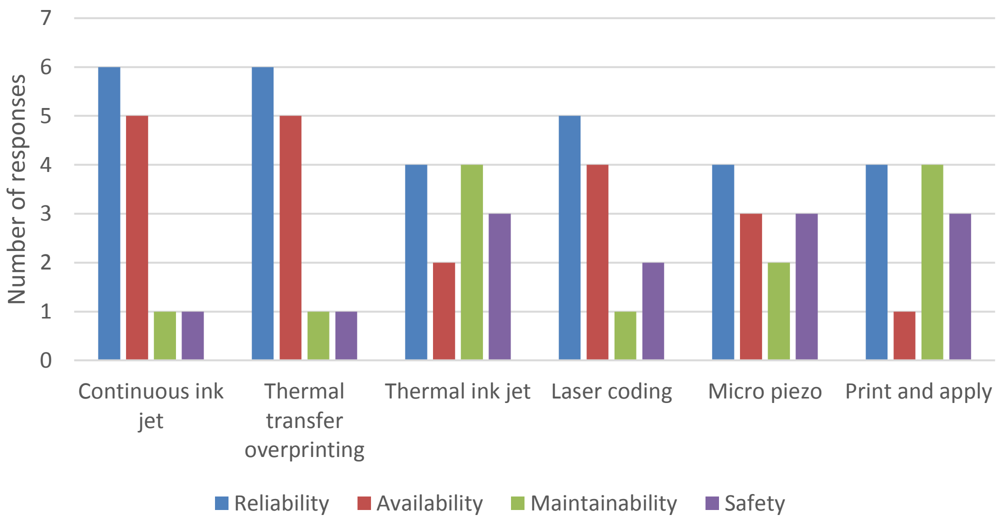


Figure D22 Most suitable printing technology from a RAMS perspective

**Feedback on question 23**

Based on the participant feedback, 13 respondents felt that integration capabilities will improve business intelligence monitoring as shown in Figure D23. Furthermore all the respective respondents felt this can be further enhanced if the respective TIJ supplier(s) were to invest in a unified control system interface. None of the participants answered no, however, 2 participants did not answer the question and both commented that they were completely unsure if there would be any benefit whatsoever.

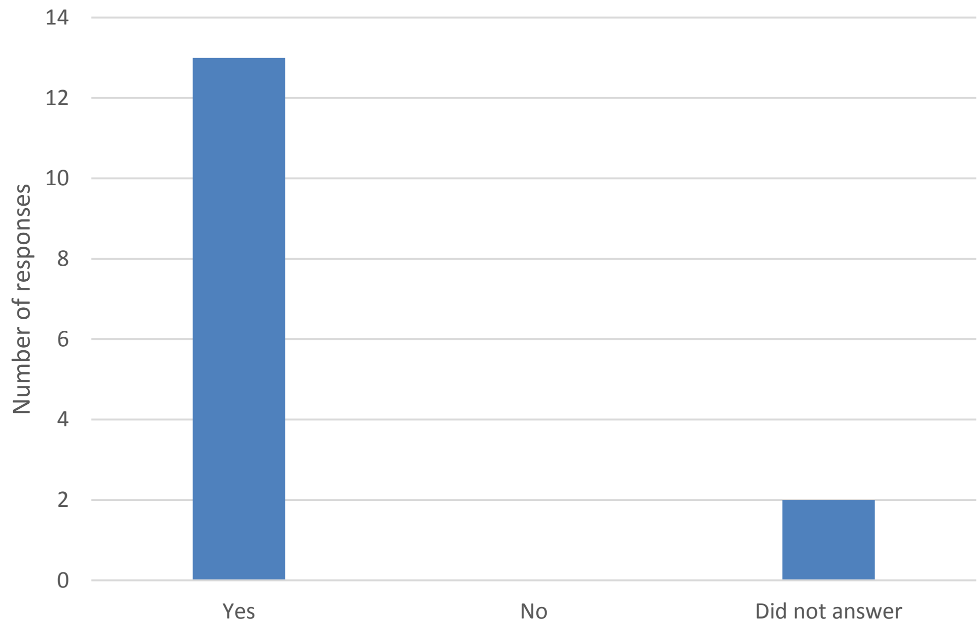


Figure D23 Integration capabilities between SAP and TIJ technology

**Feedback on question 24**

The largest risk to obtaining a readable barcode was found to be artwork that covers the corrugate packaging as shown in Figure D24, with 11 responses. The next most significant risks were line speeds being too fast and dust particles which may clog the printhead, which each received 5 responses.

Furthermore, 4 respondents believed that the corrugate conveyor belts vibration may also result in an unreadable barcode print, while 3 respondents believed that the DPI needed to be adjusted. Lastly, only 1 respondent felt that there would be no risk whatsoever in using TIJ technology. There were 2 respondents that responded with 'other' explaining that they were unsure of any risks present.

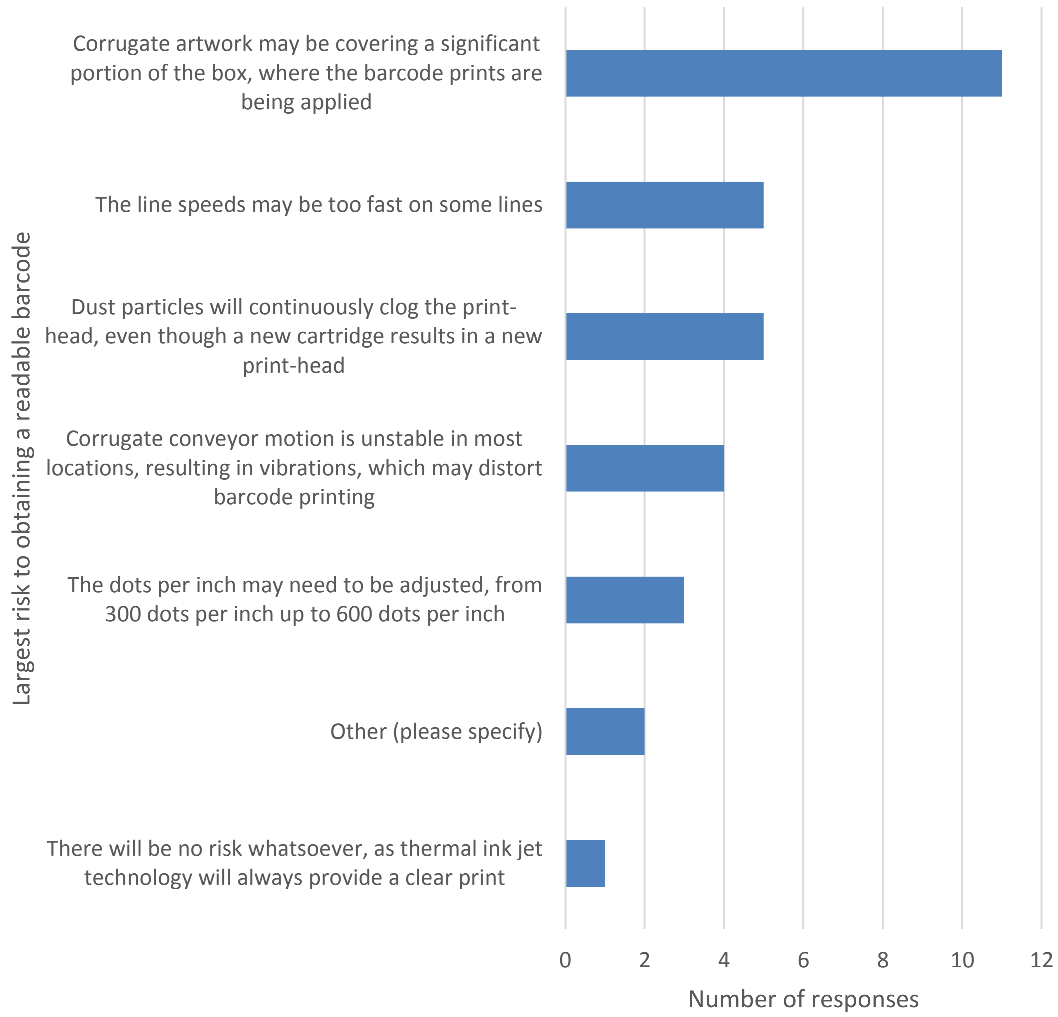


Figure D24 Largest risk to obtaining a readable barcode with TIJ technology

**Feedback on question 25**

All respondents were aware that the easiest way to save on TIJ consumable costs was to investigate the various ink types available, reduce DPI and text character requirements, as well as integrate all of the current barcodes into one 2D barcode as shown in Figure D25. Effectively there were 10 participants that selected ‘all of the below’ as an option with the remaining participants selecting the option of investigating the yield on various ink types next, followed then by reducing text size, and then DPI and barcode integration respectively.

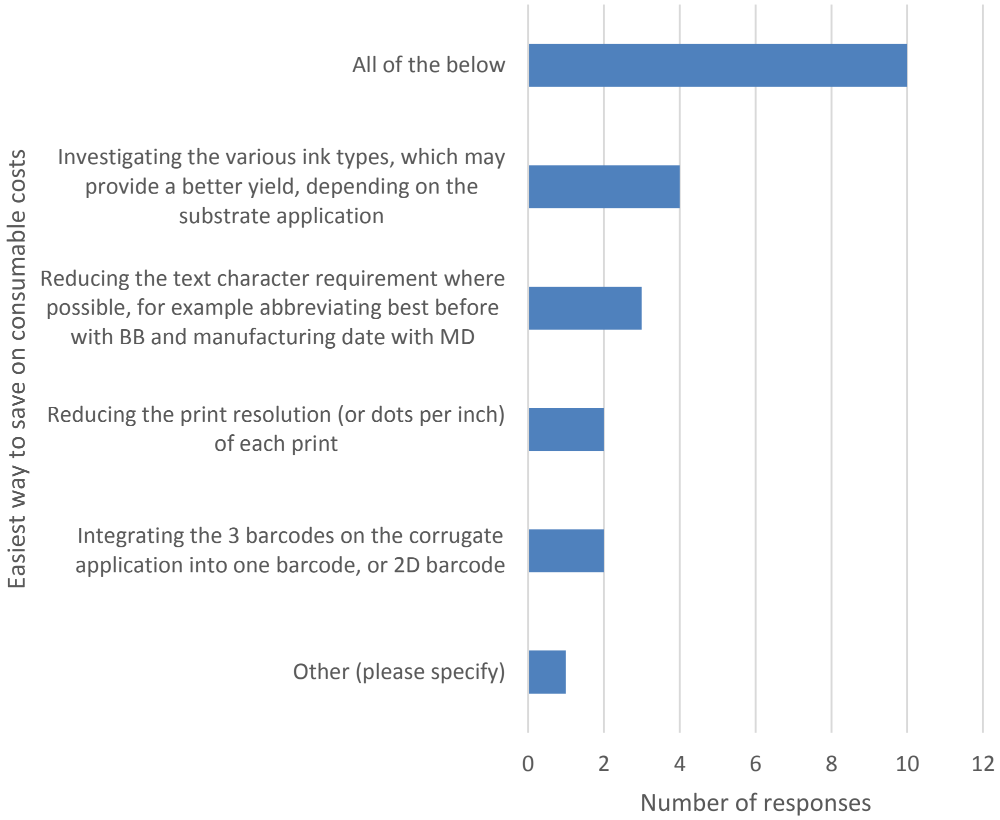


Figure D25 Simplest way to save on consumable costs with TIJ printing

**Feedback on question 26**

Most respondents were of the view that all technologies would require replacement after 5 years as shown in Figure D26. Thereafter respondents felt that CIJ technology would require replacement first, with 5 responses, followed then equally by TIJ and TTO with each obtaining 4 responses each. Print and apply obtained 3 responses whereas only 1 respondent confirmed that laser printing would require replacement after 5 years.

Based on feedback from supplier 1 TIJ technology would be able to run longer than 5 years, as it utilises a modular design with no moving parts or components like the other printing technologies. Furthermore, TIJ technology is a non-contact technology that will result in less wear-and-tear over time.

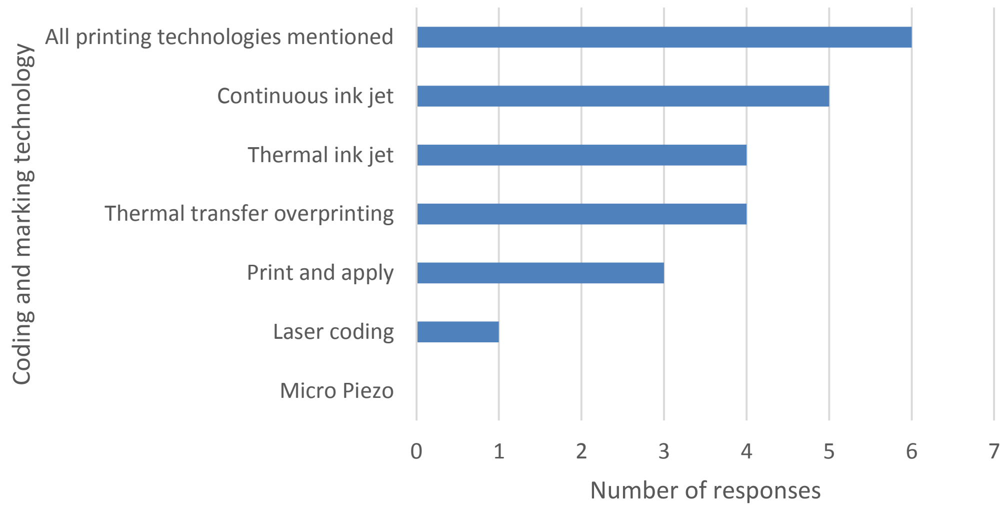


Figure D26 Printing technologies that require replacement after 5 years

**Feedback on question 27**

The main reason for most participants selecting CIJ technology as requiring replacement after 5 years is due the fact that the technology has several pneumatic and mechanical parts, which degrade slowly over time with 10 respondents confirming this, as shown in Figure D27. The next largest response was due to the fact that if a print head became damaged with CIJ or TTO technology, then this would require a completely new print head, with 9 respondents confirming this.

This was then followed with 6 respondents selecting the technology is a contact technology, which will result in accelerated wear-and-tear over time. Next to follow were reasons that included dust particles damaging the printheads and static charge which may affect the equipment, with each obtaining 5 responses respectively. Lastly, 2 participants felt that factory staff may deliberately sabotage the equipment which would ultimately result in the organisation having to purchase printing technology every 5 years at the very least.

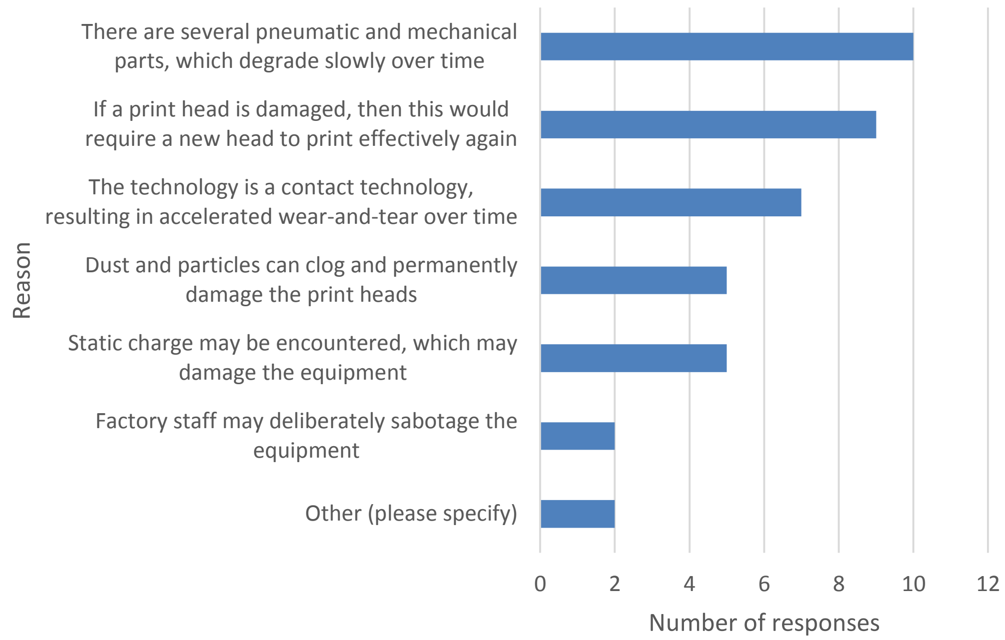


Figure D27 Reasons why the technology requires replacement after 5 years

**Feedback on question 28**

Most respondents believe that TIJ technology will last beyond 5 years, with 7 respondents confirming this as shown in Figure D28. The next technology with the largest number of responses is laser technology, with 6 respondents confirming this will last longer than 5 years, followed next by print-and-apply and TIJ technology which each obtained 3 responses respectively. Next to follow were micro piezo and CIJ technology with 2 and 1 response to each respectively.

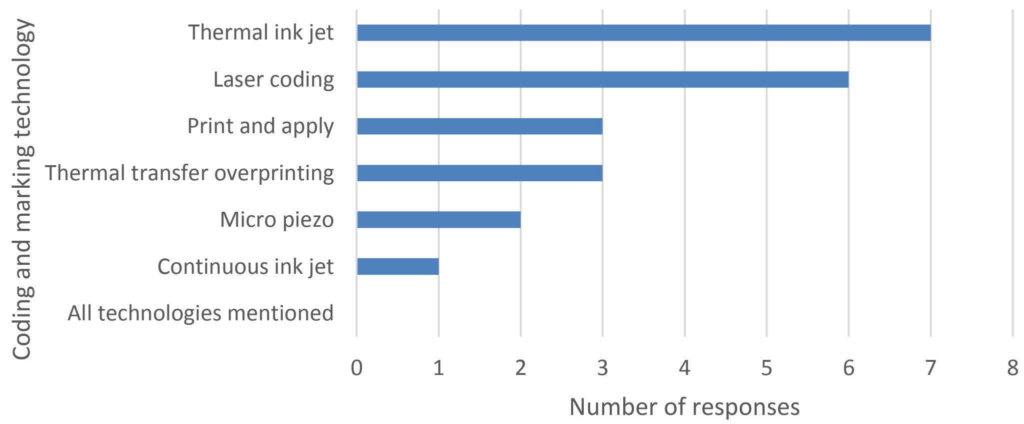


Figure D28 Printing technologies that can operate beyond 5 years

**Feedback on question 29**

Most respondents believe that the main reason that TIJ technology will longer than 5 years is due to the fact that the technology does not consist of any moving parts which reduces wear-and-tear over time with a total of 8 respondents confirming this as shown in Figure D29. The next main reasons were due to the technology being almost maintenance free, as well as the technology utilising a modular design with minimal chance of failure, with both reasons obtaining 7 responses respectively.

The third largest reason according to the respondents was due to the technology having a non-contact printhead resulting in less wear-and-tear, with 6 respondents confirming this. Only 2 respondents felt that a new cartridge replacement, which leads to the benefit of a new print head each time, would result in the technology lasting longer than 5 years. One respondent selected ‘other’ and explained they were completely unsure.

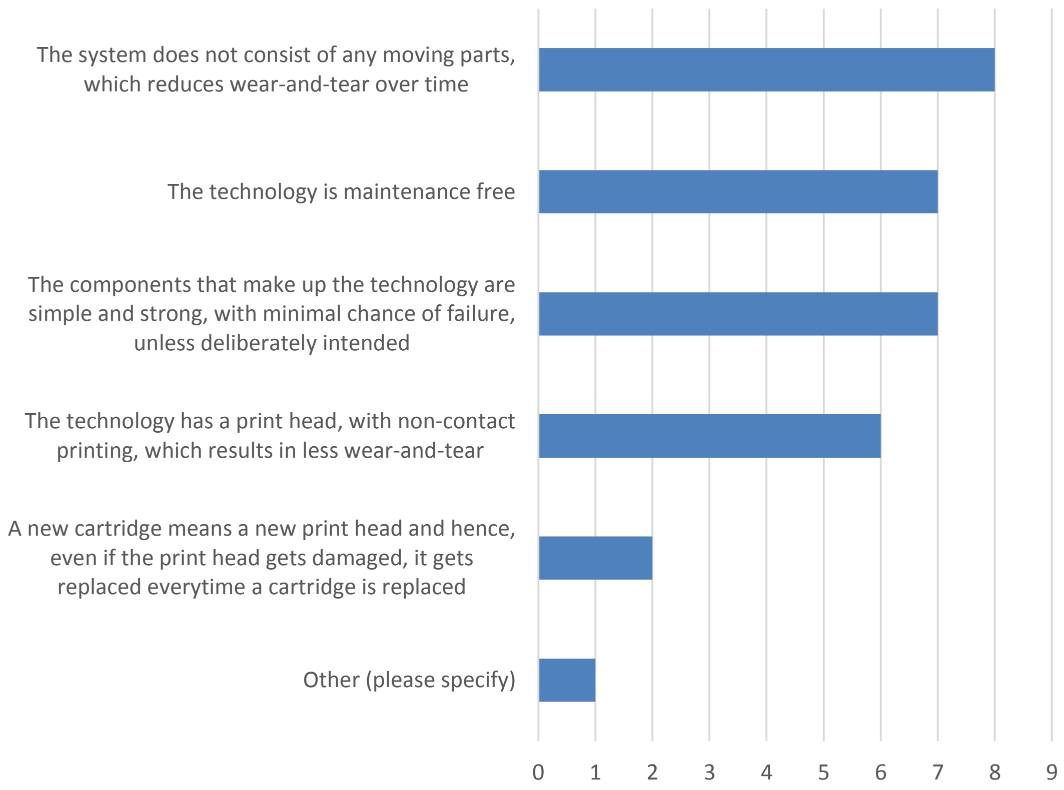


Figure D29 Reasons why the technology may operate longer than 5 years