Improving Efficiencies of island-based EBME Departments through Asset Tracking: An investigative cost-benefit analysis

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I would also like to thank my family, friends and colleagues for their patience and support during my research without which this project would not have come to fruition.

Abstract

This research study attempts to explore how implementing asset tracking technology may address the specific operational challenges faced by island-based Electro-Biomedical Engineering (EBME) departments providing insights into the unique equipment management issues and assess the technology's potential to mitigate these challenges and improve efficiency.

Following collection of data, through interviews and surveys of island-based EBME staff members, to substantiate a thorough literary review, the research results indicate several challenges pertaining specifically to island-based EBME departments as well as a clear perception amongst department members that the technology could provide a solution to many of them.

The study concludes that, whilst asset tracking implementation has the potential to assist in many operational areas, perhaps the main benefit to island-based EBME departments is in its capacity to mitigate or remove some of the high operational costs associated with geographically remote locations.

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List of Abbreviations

RFID	Radio-frequency identification
EBME	Electro-Biomedical Engineering
PPM	Planned preventative maintenance
KPI	Key Performance Indicator
FSCA	Field Service Corrective Action

Introduction

The provision of healthcare in geographically isolated locations, such as island hospitals, presents significant operational challenges for its departments, including support services such as Electro-Biomedical Engineering (EBME). Though the availability of adequately functioning medical equipment is crucial to all hospitals (MHRA, 2021), it becomes particularly pertinent when the replacement of such equipment is delayed or made more difficult due to geographical restraints and a lack of local resources (Gould & Moon, 2000).

Asset tracking technology, which utilises a radio-frequency identification (RFID) tag physically attached to a piece of medical equipment to transmit a signal back to a receiver enabling the identification of the equipment's location, provides many advantages in the management of medical equipment within organisations and 'has been shown to provide hospitals with certain benefits including cost reduction, improvements in medical care quality and work processes' (Yoo et al, 2018, p2). In addition, 'active' tags can provide enhanced functionality with the ability to store information about the equipment such as last serviced date, status condition, humidity and temperature (Anstee, 2017, p12).

The various benefits of asset tracking are widely acknowledged with regard to medical equipment management; however, they also require significant financial investment, often difficult for many small organisations to justify.

Problem Statement

EBME departments must maintain and manage medical equipment effectively to ensure the provision of high-quality healthcare (MHRA, 2021). This requires a robust program of planned preventative maintenance (PPM) along with prompt execution of reactive maintenance. However, in an island setting, the required efficient management and timely maintenance is often hindered by limited access to local resources, such as spare parts and specialised expertise, as well as the logistical challenges related to geographical location (Gould & Moon, 2000). These obstacles often result in increased downtime of equipment, lack of patient care provision and costly financial repercussions.

Difficulties in finding medical devices are commonplace in many hospitals (Anstee, 2017, p.4) and have various consequences as illustrated in figure 1. These

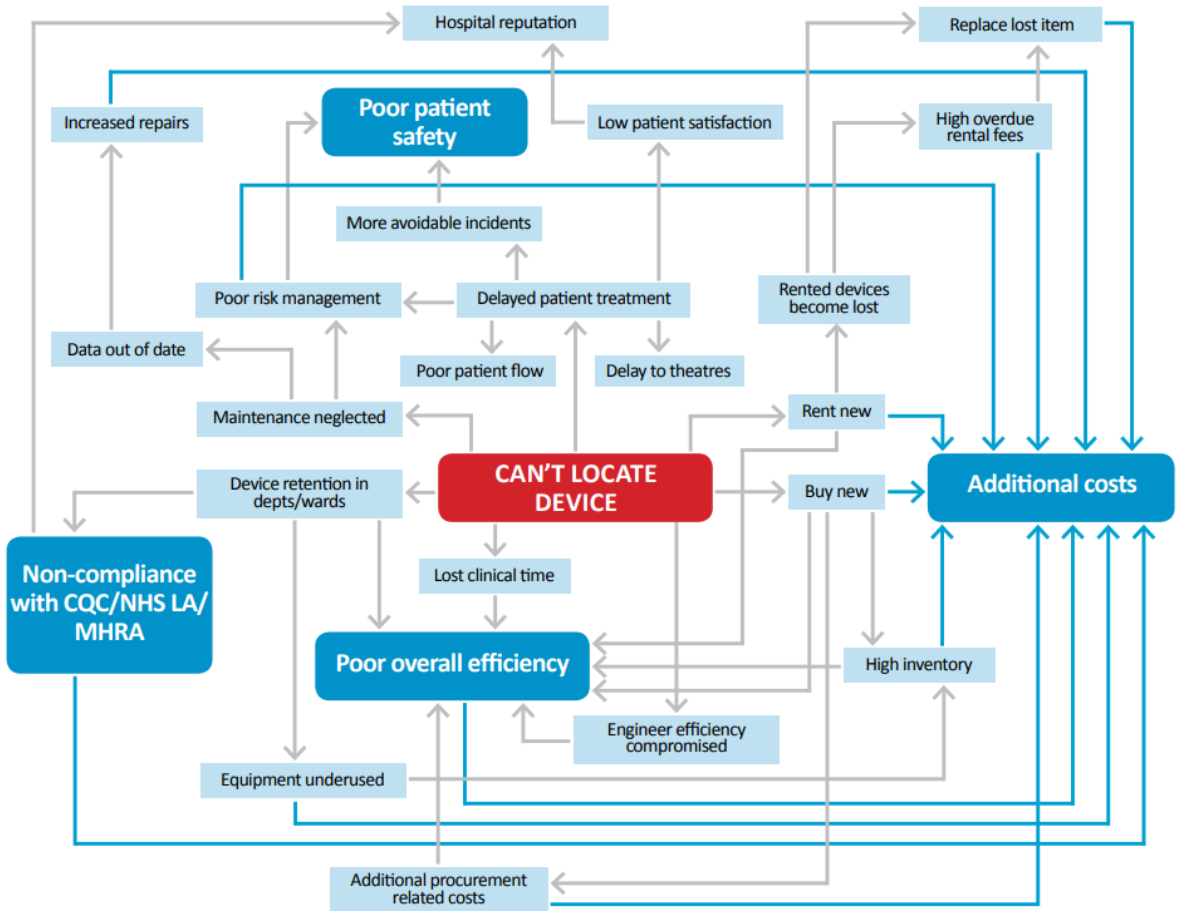

Figure 1 - Consequences of inability to find medical equipment (Anstee, 2017)

consequences are often exacerbated when the healthcare facilities' location is more inaccessible as shown in table 1.

Table 1 - Consequences of mismanagement of medical equipment

Event	Consequences
General misplacement	In addition to an ineffective use of engineers' time in searching for items, misplaced equipment can result in service and maintenance lapses increasing the risk of failure impacting patient care.
Manufacturer service visits	Equipment that cannot be located during external manufacturer service visits results in equipment missing important periodic preventative maintenance impacting on the level of patient care and reduced value for money service contacts.
Manufacture corrective action required	Delays in the ability to locate equipment that is subject to field safety corrective action (FSCA) issued by manufacturers or the MHRA poses significant patient risk.
Misplacement but required	Critical items require prompt replacement requiring the need for loan equipment when items cannot be found incurring expensive rental and, particularly, shipping costs (Baldacchino, 2018,) attributed to island jurisdictions, further adding to the inconvenience of loss.
Complete Loss	Ultimately, if equipment cannot be found it will need replacing necessitating further financial expense subject to the increased transport costs associated with remote locations.

Questions & Objectives

Dealing with operational perceptions rather than specific technological function, the intention of this study is to explore how the implementation of asset tracking technology may address the operational issues related specifically to island-based EBME departments. It should provide the reader with an insight into their unique equipment management challenges, assessing the technologies' potential to tackle them and improve efficiency, posing the following questions and objectives set to answer them (Table 2).

Table 2 – Research Question, Sub-Questions and Objectives

Research Question	
How can the implementation of asset tracking systems impact the operational efficiencies of medical equipment management in an isolated, island-based EBME department and what is the cost-benefit analysis of such implementation?	
Sub Questions	
1	How can the current medical equipment management challenges faced by island-based EBME departments be assisted by asset tracking implementation?
2	What are the perceptions of the implementation of asset tracking to impacting EBME department efficiencies?
3	How can the costs of implementation and the potential benefits be assessed?
Objectives	
1	Identify current challenges faced by island-based EBME departments with regard to medical equipment management.
2	Evaluate the potential benefits that asset tracking system implementation may bring to improve EBME department efficiency.
3	Conduct a cost-benefit analysis of the implementation of asset tracking technology in an island-based EBME department.
4	Provide recommendations, based on research findings, for the effective implementation of asset tracking technology within island-based EBME departments.

Literary Review

To fulfil the research objectives a comprehensive literary review of academic journals, books and scholarly articles (appendix A) was first carried out to establish what information was available regarding common challenges faced by island-based healthcare organisations and their departments, the pros and cons of asset tracking technology and identify any gaps in the research. Using the search terms in table 3, the review revealed some valuable information with regard to both asset tracking technology and island-based healthcare.

Table 3 - Literary Review Search Terms

Search Terms						
Island-based	Healthcare	Engineering	Geographically isolated	Asset tracking	Remote	EBME

Island-based Themes

Whilst unsuccessful in revealing any evidence specific to island-based EBME departments, the review did establish two key themes to island healthcare provision that have relevance to the study.

The first, isolation due to physical geographical location, posing issues with regard to transportation of goods to remote locations, logistical difficulties and lack of local expertise. The second, a consequence of the first, is higher operational cost with the review revealing that islands must pay more to achieve that same level of mainland healthcare provision due to a dis-economy of scale (Hotchkiss,1994). It is also proposed that these locations are subject to an 'island penalty' due to their small size, isolation and increased transportation costs (Gould & Moon, 2000).

Asset Tracking Themes

The benefits and merits of asset tracking to healthcare, including engineering departments, were prevalent in the material further endorsed by the MRHA (2021) statement that 'medical equipment should be adequately deployed, tracked and utilised and helps to address concerns around risk management and field safety notices.' Another report went as far as recommending asset monitoring should exist in all hospitals to improve quality and efficiency (Carter, 2016).

Though much of the literature suggested that asset tracking had the potential to solve some of the issues faced by island-based departments, it tended to highlight the benefits over the shortcomings of the technology. However, one source provided some warning that users should be cautious in their expectations due to different environments and unique characteristics of different organisations (Janz et al, 2005), terms appropriate to island-based departments. In addition, the review acknowledged the financial investment factor of asset tracking implementation, in that EBME departments must maintain equipment in a cost-effective manner (Aruna et al, 2018) and use an economic approach that maximises personal safety whilst minimising operation costs (Jardine et al, 1997).

Research Gaps

Although the review highlighted some key themes, much of the literature is dated and relates to general healthcare, identifying a potential gap in the research and emphasizing that investigation is necessary to consider the unique challenges of island-based and geographically remote EBME departments.

Methodology

While the literature review offered insights into the primary question, it was anticipated that empirical evidence would be necessary to address the specific sub-questions and corroborate information raised in the literary review. Following a comprehensive ethical review the methodology outlined in fig.2 was followed to collect both qualitative and quantitative data. Observing ethical standards and confidentiality throughout, this mixed-method approach was used to better triangulate the evidence by tackling varying aspects from different perspectives (Bell & Waters, 2018). Data was analysed using thematic, content and statistical analysis techniques before referring back to the established theoretical framework to identify any similarities or differences, determining findings and ultimately drawing conclusions.

As this research focused on the challenges asset tracking may address specifically pertaining to island-based EBME departments, participants were chosen from the EBME departments at *Jersey General Hospital* and Guernsey's *Princess Elizabeth Hospital,* both in the Channel Islands. The stakeholder analysis diagram (fig.3) illustrates the groups that were chosen to focus on for data collection and the context diagram in fig.4 shows their association with regard to the management of medical equipment.

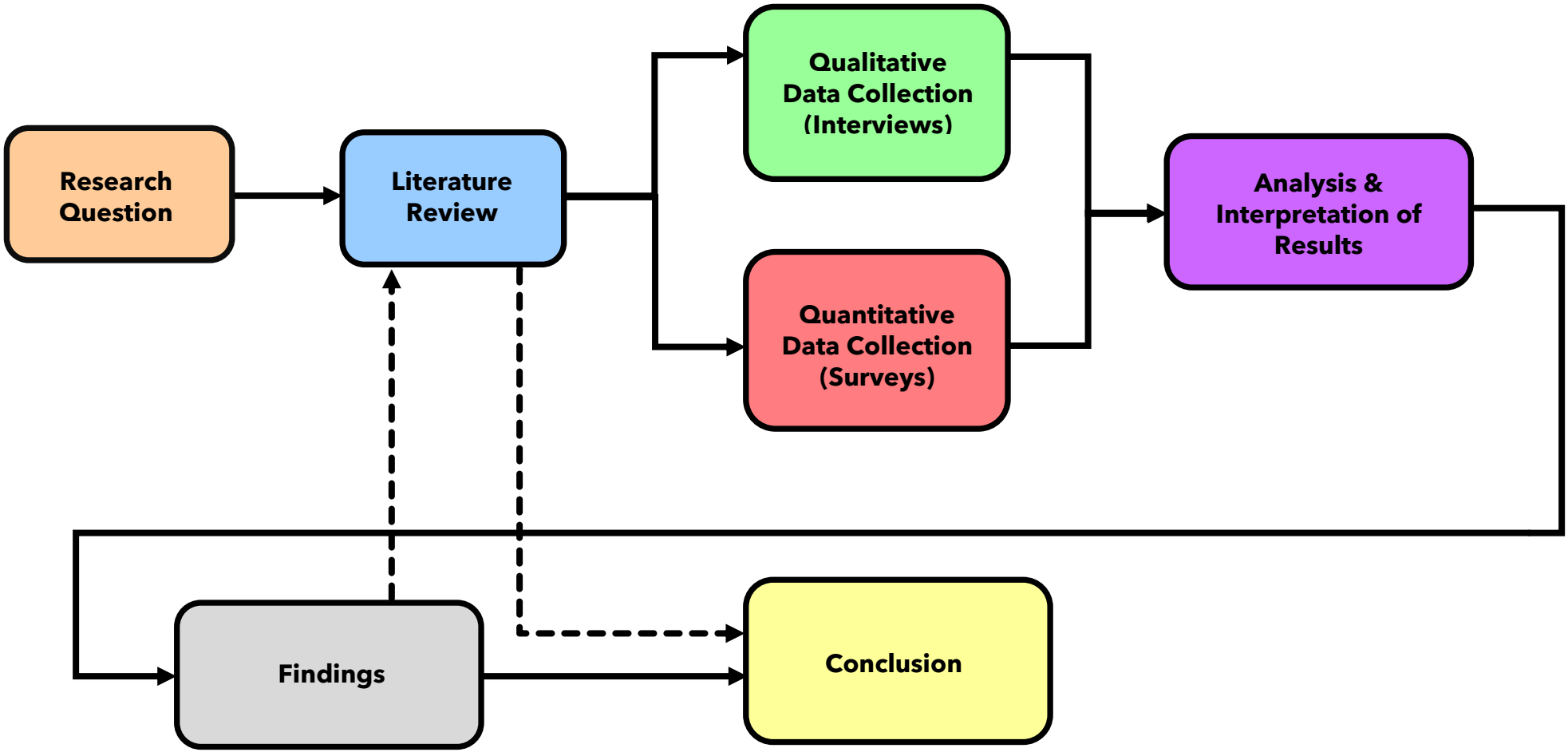

Figure 2 - Methodology Process Map

Figure 3 - Stakeholder analysis with chosen participants highlighted in green.

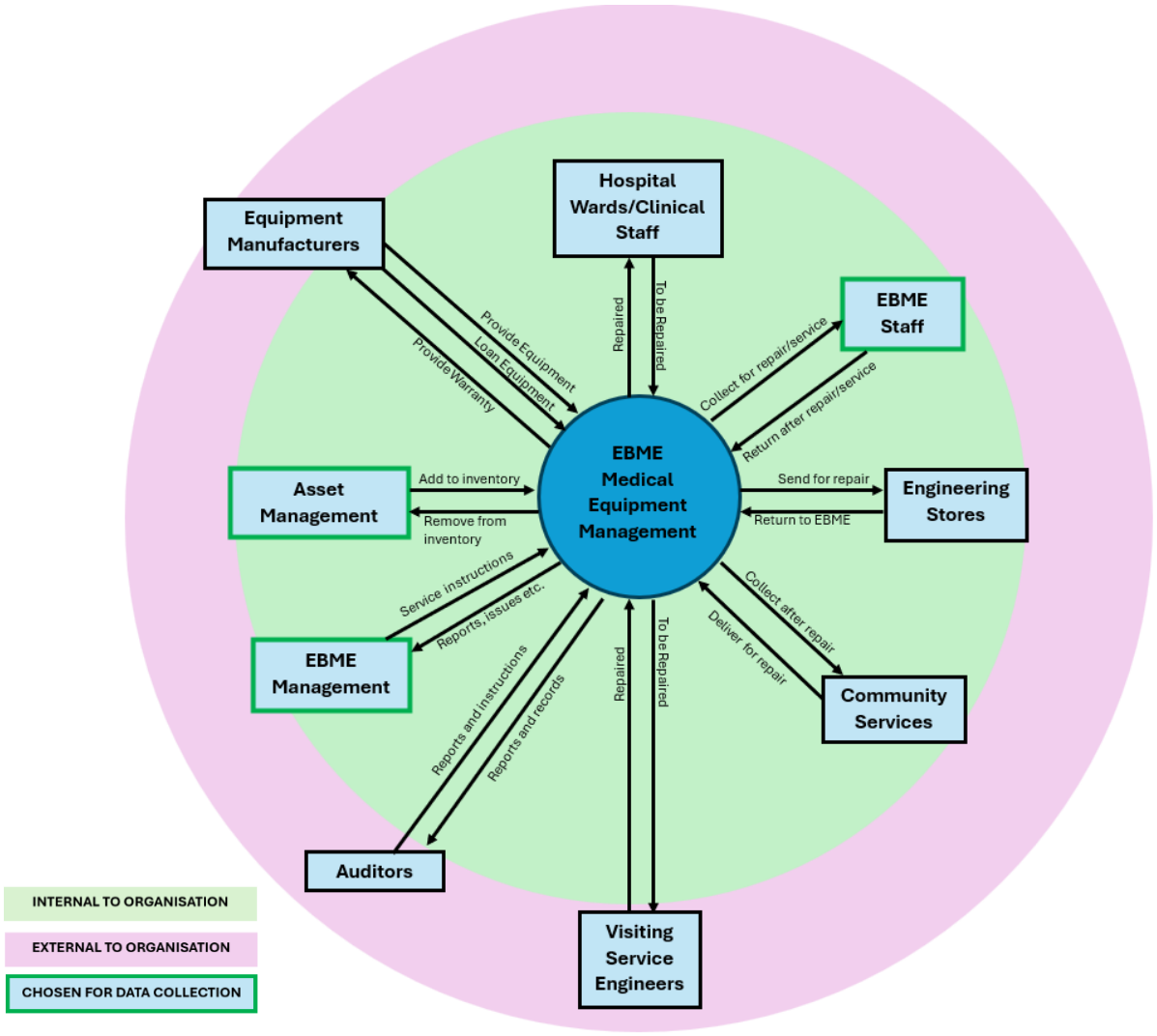

Figure 4 - Context Diagram of potential participation groups with regard to medical equipment management.

Qualitative Data

Qualitative data was collected through the use of a semi-structured interview delivered in a one-to-one setting using 23 open-ended questions (appendix B), with five senior members of the EBME, Estates and Asset management departments across both hospitals. Interviews were carried out to gauge perceptions on the challenges faced by isolated engineering departments and how asset tracking could impact those challenges.

Quantitative Data

Qualitative data was collected using a 16-question online survey (appendix C) issued electronically to 28 EBME engineers across both EBME departments. The survey aimed to establish and quantify, where possible, the main challenges experienced by engineers within an island-based EBME department determining their thoughts on departmental challenges, time spent carrying out certain tasks and their perceptions on the impact of introducing asset tracking. Due to the relatively small sample size the survey utilised a 4-point and 5-point Likert scale on several questions to ensure a forced response, prompting respondents to choose the most plausible option (Busayo, 2024) and avoid ambiguity within the data. After a trial pilot survey, the final survey was completed by 21 respondents providing a response rate of 75%.

Secondary Data

A sample of past PPM sheets was also scrutinised to evaluate existing equipment management practices covering the 2022/2023 maintenance period (appendix D).

Results & Analysis

Content Analysis

Interview transcripts were combined, and content analysis software utilised to measure word frequency in the form of a word cloud (appendix E) which showed a propensity for the following terms (Table 4).

Table 4 - Most Frequent Transcript Words

Most Frequent Terms							
Time	Maintenance	Service	Medical	Asset	Islands	Find	Devices

Thematic Analysis

A thematic analysis process of familiarisation, coding, theme generation, review, defining and naming (Braun & Clarke, 2021) was used to provide a deductive and semantic approach to analysis of the qualitative data (appendix F). This assisted in avoiding confirmation bias by ensuring objectivity and reliability (Braun & Clarke, 2022) identifying four main emerging themes from the data (fig.5).

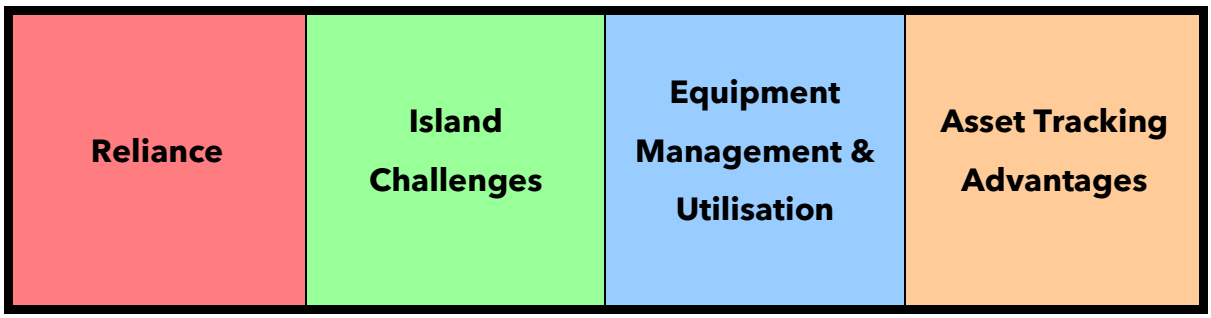

Figure 5 - Emerging Themes from Thematic Analysis

Reliance

One interviewee stated that 'a large number of medical devices are currently supported by off-island suppliers' owing to a lack of local specialist expertise and both EBME departments were found to rely on third party resources including external service engineer visits and the transportation of spare parts to the islands, a reliance described as 'particularly problematic during the pandemic' by another member of staff. A need of a 'bigger spares holding because of time frames to get items onto the island' including equipment and parts was identified by several staff. Those interviewed thought that asset tracking would be a benefit in maximising the time of visiting engineers by eliminating equipment searches, reducing the need for re-visits when items cannot be found in time or when it is realised the equipment is no longer owned by the organisation.

Island Challenges

Though it was thought that the geographical location didn't directly impact the management of medical equipment per se, it was felt that being based on an island presented significant challenges with regard to logistics, increased costs, onboarding equipment, freight and additional fees with one interviewee simply stating that 'everything just takes longer to rectify'.

An inability to borrow equipment from nearby trusts results in purchasing an excess of spare equipment and parts to bolster resilience, some of which may never be used. Questionable reliability of transport in and out of the islands further compounds these issues adding delays to receiving replacement equipment and service support.

The aforementioned reliance on third party service contracts was also said to come at a premium as companies had to factor in travel and accommodation costs for visiting engineers, again emphasizing a need to maximise engineers time once on the island. Similarly, the associated costs involved in sending local staff on training to mitigate the need for visiting engineers was cited as a financial implication.

Equipment Management & Utilisation

Whilst engineers were praised for their work in initial on-boarding of equipment, an inability to track equipment once it had left the engineering department was said to create huge labour time losses in searching for equipment for subsequent service, PAT testing and maintenance.

As well as missed equipment requiring, the above-mentioned costly revisits, these difficulties in locating items were also said to present increased risks in being unable to quickly removing items subject to field safety notices from service.

As well as improving these areas, asset tracking was also considered to assist in reducing the amount of lost equipment and associated replacement costs as well as helping with future planning and life-cycle replacement.

Interviewees mentioned various general operational benefits asset tracking would bring including location of equipment for PPM, consistency in procurement, onboarding and disposal of equipment and ability to digitally store asset information such as service histories to provide valuable KPI data to enable continued operational improvements with one interviewee saying that 'when you're…looking for equipment you will be able to see specific pieces of equipment that are coming close to their service date'.

Many of those interviewed felt a lack of responsibility of ownership amongst clinical teams had led to a culture of siloed decentralisation of equipment with departments reluctant to share equipment with others in the fear that it would not return. Interviewees felt that the ability to know where equipment was 'in real-time' would do much to diminish this mistrust and encourage better utilisation of equipment.

Underutilisation was seen as an issue due to the need to hold excess equipment as spare stock to mitigate the increased transportation time in shipping equipment to the island. Better visualisation of equipment was thought to improve the utilisation of existing items and potentially provide evidence for 'reducing the amount of equipment that is needed throughout the hospital' as one interviewee put it. Another illustrating the point saying 'can ownership still be justified if an item has

not moved from storage for 12 months' cited a reduction in equipment could lead to direct savings from purchase, maintenance and servicing.

Asset Tracking Advantages

A clear level of support for asset tracking was evident in all interviews and, whilst implementation time, cost and coordination of resources were cited as potential challenges, improvements to efficiency, staff productivity, reduced equipment replacement costs and enhanced KPI data were thought to be key benefits.
As one interviewee put it, 'knowing the availability of medical devices and visibility of locations would dramatically increase efficiency within the department' with another member of senior management stating that 'it was an essential step in bringing the organisation to where it needed to be' giving it their full support.

Asset tracking technology was also cited as providing benefits with regard to risk reduction, not only in freeing up clinical staff from searching for equipment to concentrate on patient care, but in its capability of recording other useful information such as equipment service due dates and calibration history ensuring the highest standard of maintenance and reducing the chance of items being missed during PPM. In addition, the technology was viewed as a large benefit with regard to field safety notices with one interviewee saying that 'the department would be better placed to remove affected items from service as soon as possible using asset tracking'.

Qualitative Survey Feedback

The open-answer section of the survey for respondents to leave any additional comments on their feelings toward the subjects covered, reiterated many of the themes of the interviews with comments such as 'I think asset tracking would be a great improvement to help our service' and 'the only downside I can think of for asset tracking is the amount of time it will take to initially set-up but will hopefully be offset by future time saved in locating assets'.

Statistical Analysis

Time Served

The majority (62%) of those surveyed had served 9 or more years in the EBME department (fig.6) with the average time served calculated at 6 to 8 years.

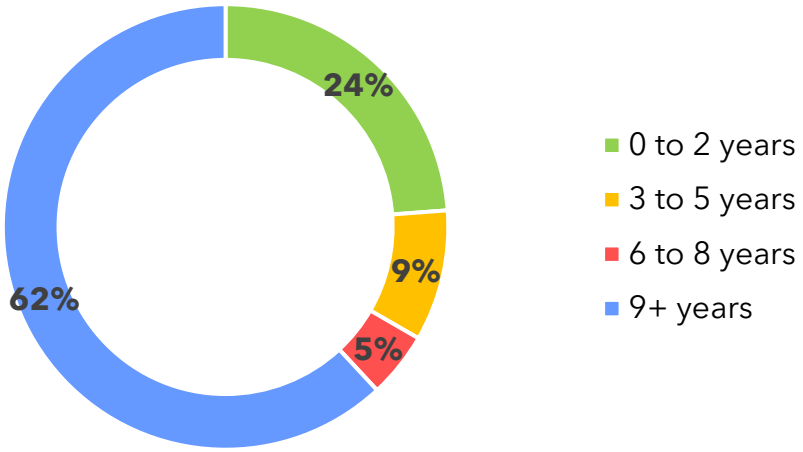

Figure 6 – To the nearest year, how long have you worked in your EBME department?

Primary Challenges

The vast majority of the 21 respondents thought that the primary day to day challenge with regard to medical equipment was difficulty in locating equipment, with a mode of 13 (fig.7).

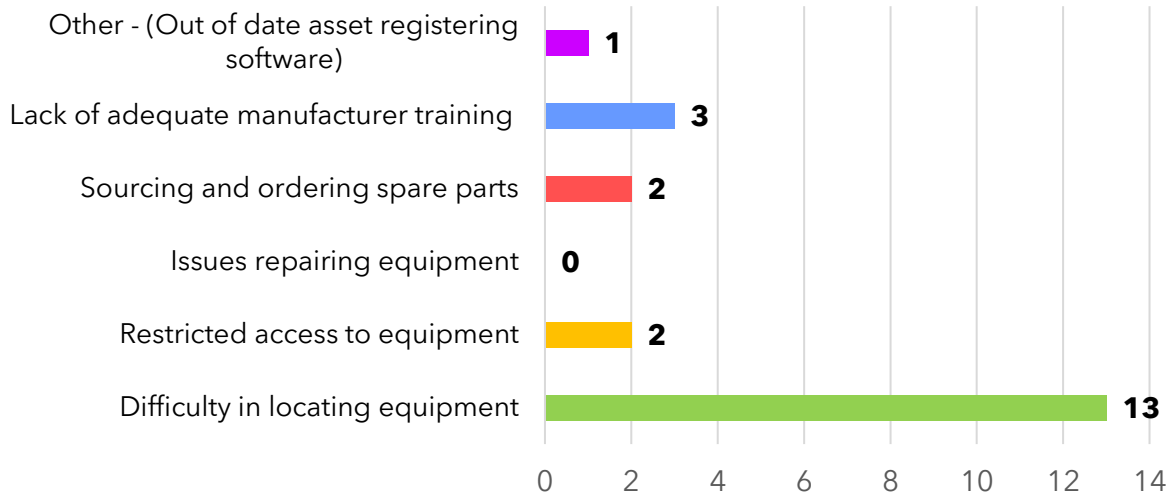

Figure 7 – What is the primary challenge with regard to medical equipment in your day-to-day tasks?

In addition, 38% said they faced these difficulties on a weekly basis and 29% on a daily basis (fig.8).

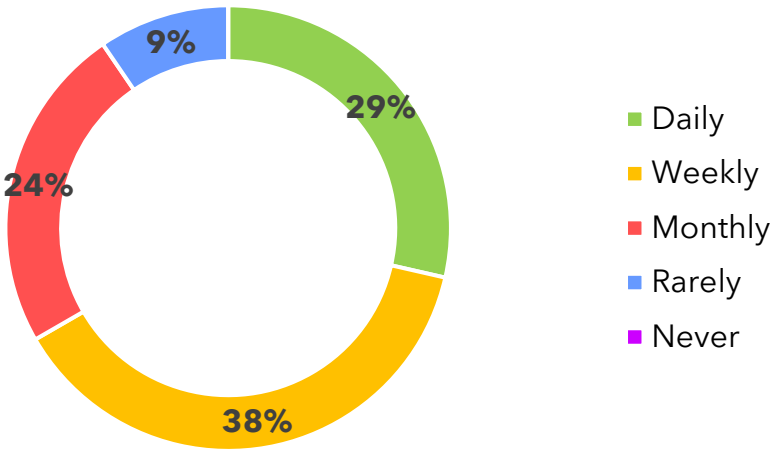

Figure 8 – How often do you face challenges in locating medical equipment for repair or service?

Time Locating Equipment

The data provided some quantification of this with the average respondent saying they spent more than 1 hour but less than 3 hours searching for equipment per week (fig.9).

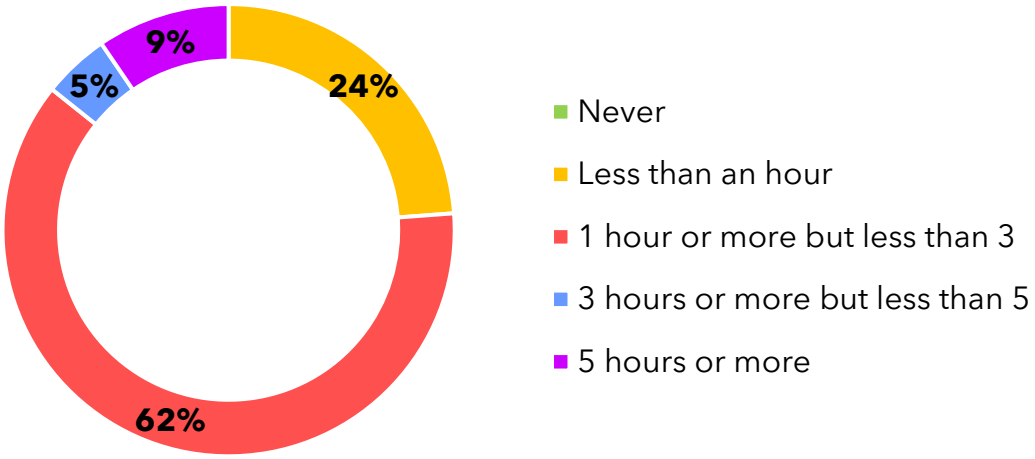

Figure 9 – On average, how long would you say you spend looking for equipment per week?

Challenges Locating Equipment

However, whilst a total of 67% of engineers felt they faced challenges in locating equipment at least weekly (fig.8), on average respondents said they rarely had to locate equipment for visiting service engineers from off-island (fig.10) with only 38% saying that this was a weekly (14%) or monthly (24%) occurrence.

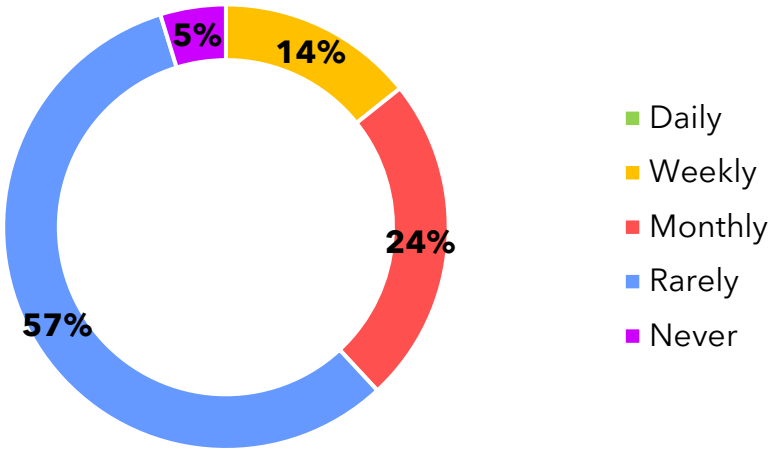

Figure 10 – How often do you face challenges in locating equipment for visiting service engineers?

Similarly, locating equipment for field safety corrective action was also rare, but just over a third said they did have to do this on a monthly basis with 10% saying this occurred weekly (fig.11).

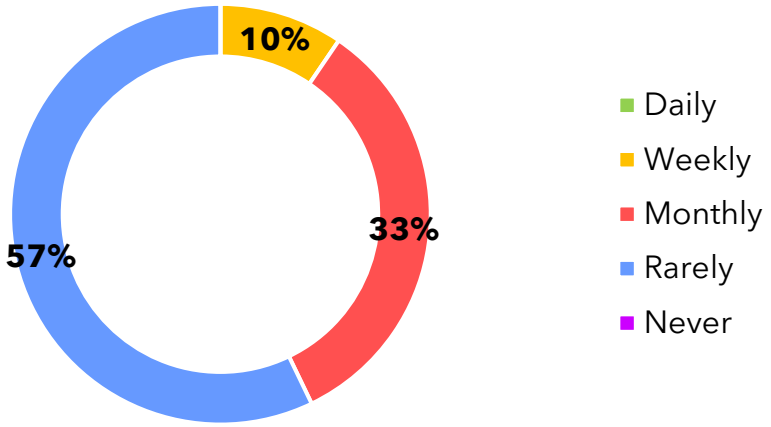

Figure 11 – How often do you have to locate equipment for field safety corrective action, such as manufacturer software upgrade or return to manufacturer repair?

The average respondent, however, did say they occasionally require loan equipment to be shipped to the island as a replacement for faulty equipment with 33% saying that this happens frequently (fig.12).

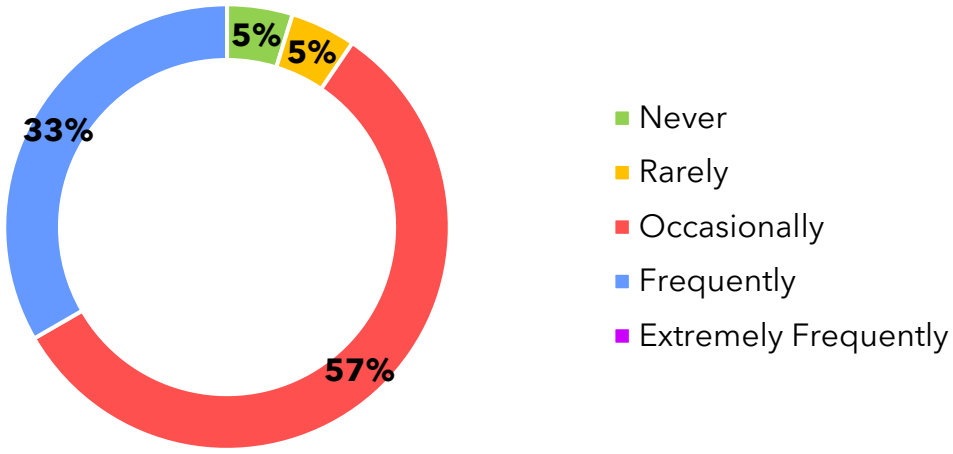

Figure 12 – How often do you require loan equipment to be shipped over to temporarily replace faulty medical equipment?

Improving Efficiency and Effectiveness

Whilst 38% felt that existing equipment management was effective, on average the response deemed it ineffective (fig.13) and 90% of respondents answered that they felt implementation of an asset tracking system would reduce the time spent looking for equipment (fig.14).

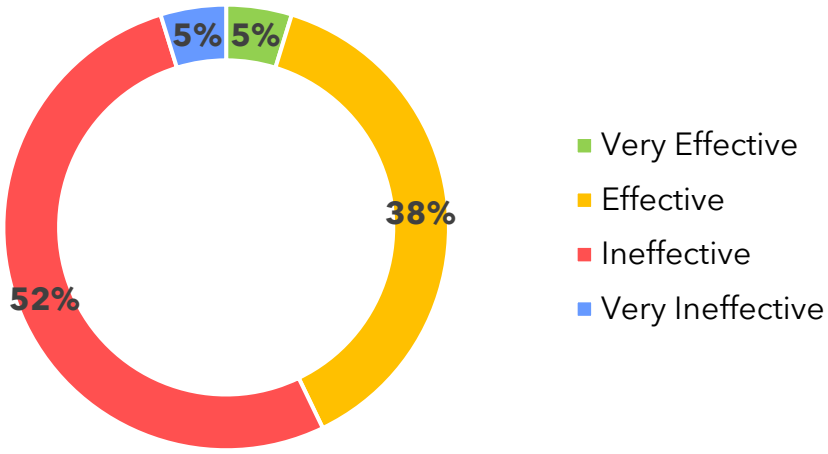

Figure 13 - How would you rate the effectiveness of medical equipment management within your department?

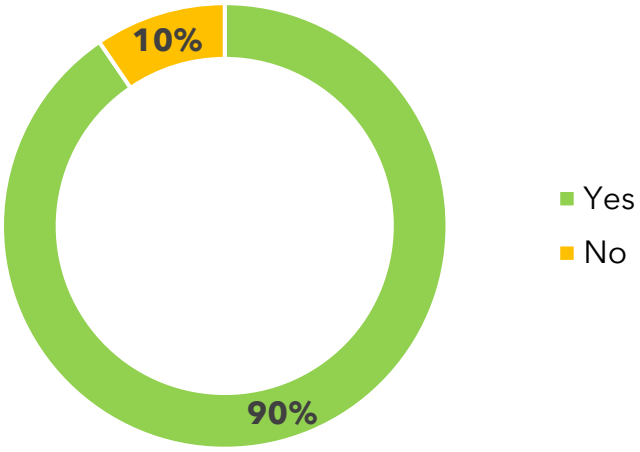

Figure 14 - Do you feel that an asset tracking system would help in reducing the time spent looking for equipment?

An overwhelming 95% (fig.15) agreed it would improve the efficiency of managing medical equipment within the department with 95% (fig.16) also feeling that it would improve efficiencies with regard to planned preventative maintenance (PPM).

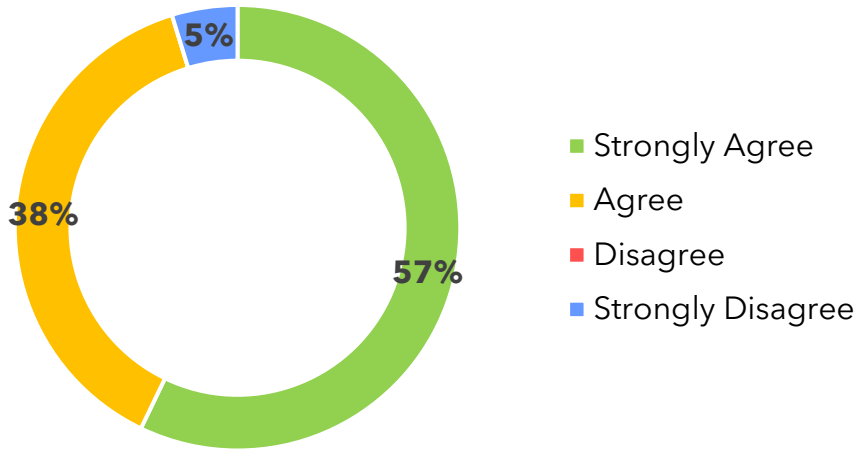

Figure 15 - Do you believe that implementing an asset tracking system would improve the efficiency of managing the medical equipment within your department?

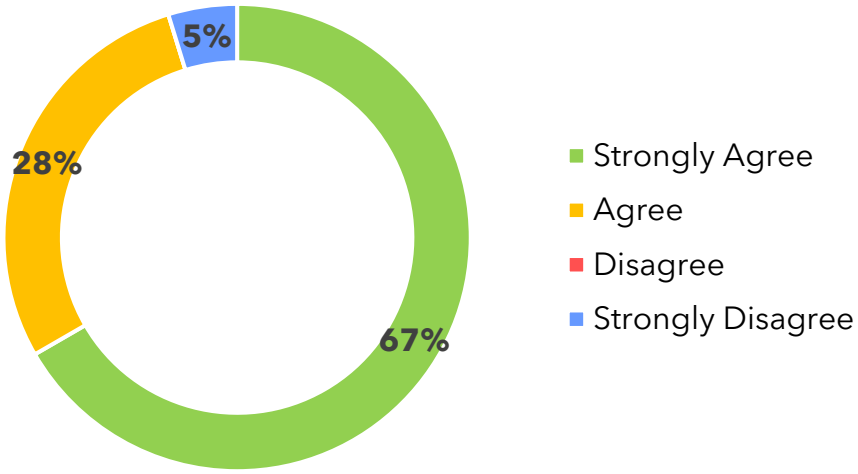

Figure 16 - Do you believe that implementing an asset tracking system would improve the efficiency of carrying out planned preventative maintenance (PPM) within your department?

Main Benefits & Challenges

The main benefit to implementing an asset tracking system was thought to be improved efficiency in locating of equipment with 62% in agreement (mode of 13) whilst 29% felt it would be improved maintenance scheduling and 9% improved inventory management (fig.17).

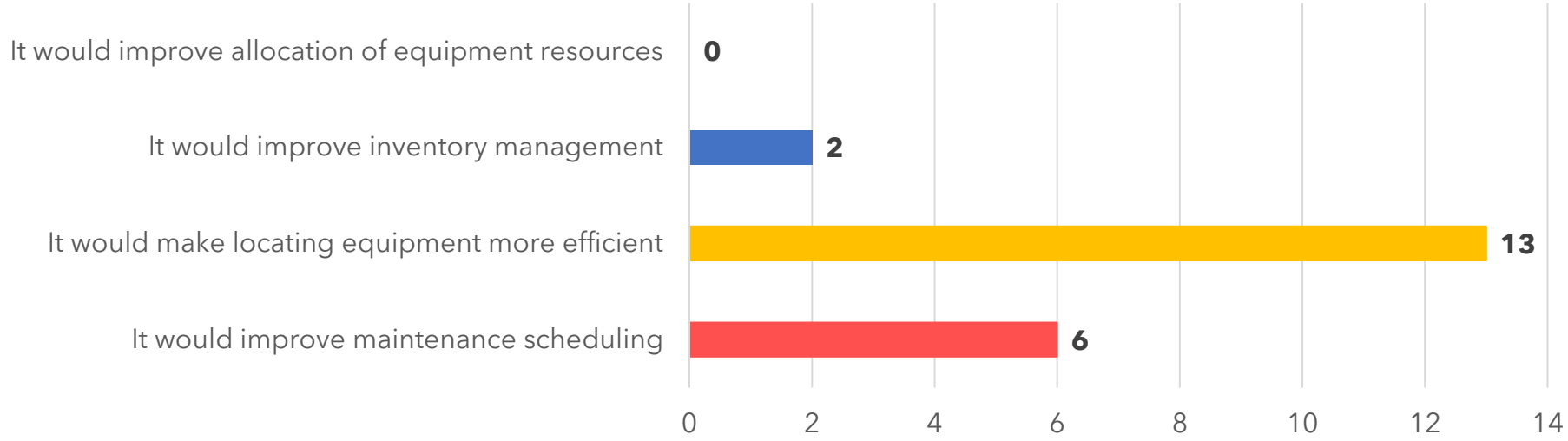

Figure 17 - What do you believe is the main benefit that asset tracking software could bring to your department?

Main challenges evoked a more variable response with engineers giving a range of answers of initial implementation and training, resistance to change, increased administration and tracking system maintenance and availability of resources (fig.18).

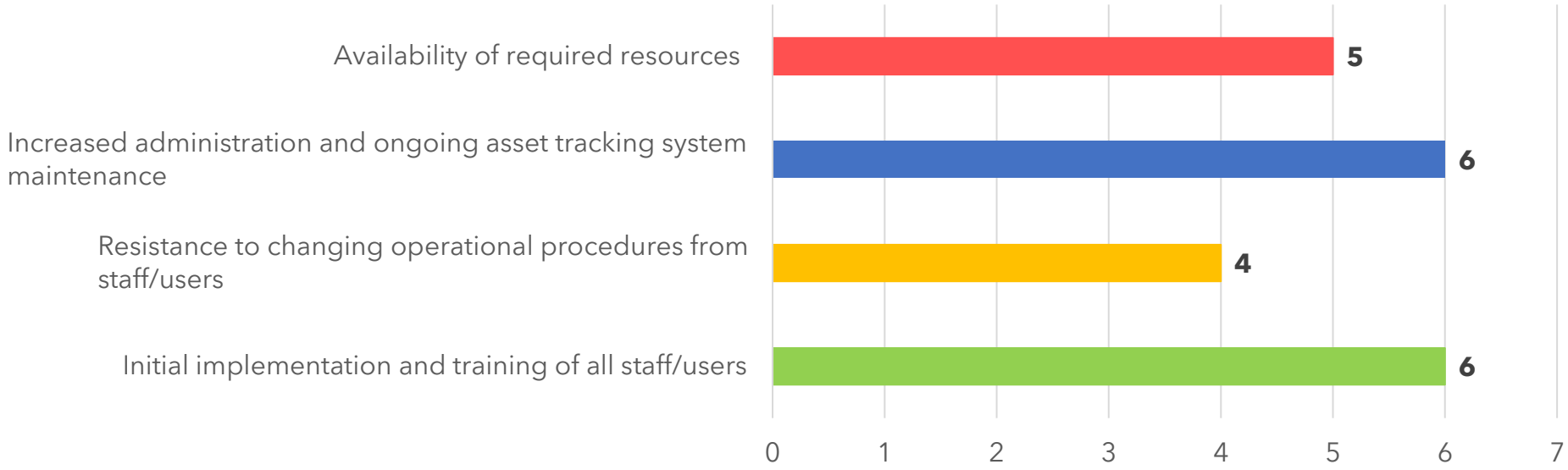

Figure 18 - What would be the main challenge to implementing asset tracking software within your department?

Confidence

However, despite acknowledging these challenging, overall confidence in the implementation of asset tracking was exceedingly high. The average response was very confident and 91% were confident or very confident (fig.19) that implementation would be successful.

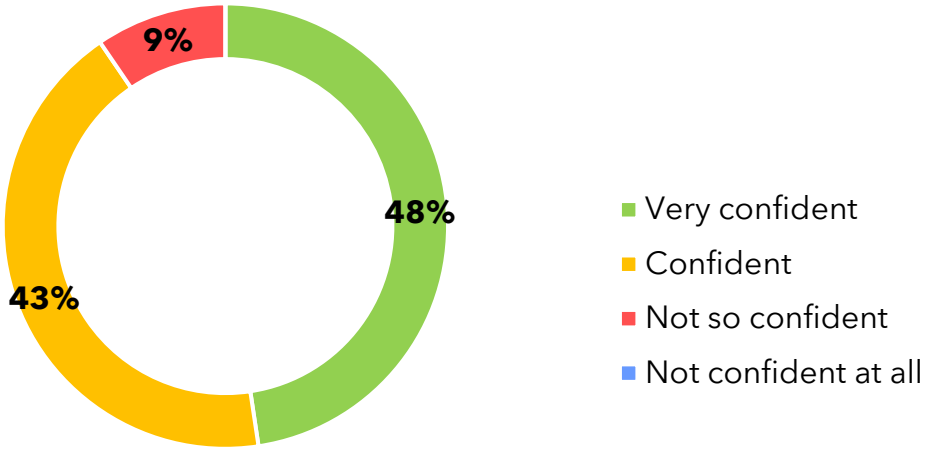

Figure 19 – How confident are you that implementation of an asset tracking system would prove successful?

Similarly, 100% (fig.20) of respondents felt that the benefits after implementation would be successful, with an average response of '*Yes, definitely*'.

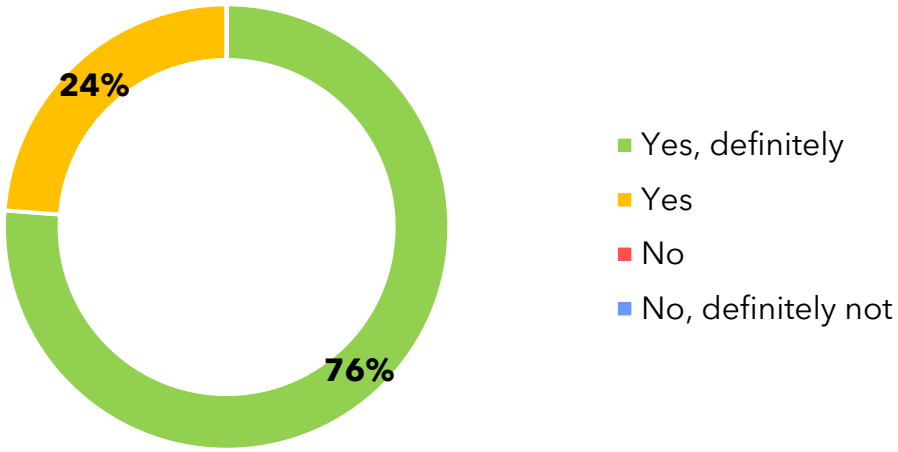

Figure 20 – Do you believe that the benefits of introducing an asset tracking system would by worthwhile?

Cost-benefit Analysis

While little information regarding cost-benefit has been revealed in this research the survey data did allow for quantification of a labour cost saving. This is based on the 18 engineers at Jersey General Hospital using the mean engineer hourly rate (GoJ, 2024) and the modal answer for hours spent looking for equipment per week, as seen in table 5.

Table 5 - Labour Cost Saving Calculation

Mean engineer hourly rate	£26.46
Modal time looking for equipment per week	2 (average of ≥1 to <3 hours)
Quantity of engineers	18
Total weekly cost	£952.56
Average working weeks per year	48
Total yearly cost to looking for equipment	**£45,722.88**

One of the EBME departments has a preliminary anticipated spend of £146,000 earmarked for an asset tracking implementation project based on procurement research with providers. Dividing this spend by the prospective yearly labour savings would achieve an investment payback period of just over 3 years (fig.21).

$$\frac{Anticipated\ Investment}{Total\ Yearly\ Cost} = \frac{£146,000}{£45,722.88} = 3.19\ years$$

Figure 21 - Calculation of asset tracking investment payback period.

Findings

To restate the research problem, Island-based EBME departments must effectively maintain medical equipment to ensure adequate healthcare can be provided, however, they are often hindered in this task due to geographical location from the mainland. This section will attempt to analyse the research results and establish findings with regard to asset tracking technologies' perceived potential to impact these problems and improve department efficiencies.

Accurate Representation

Of those surveyed, many staff had served 9+ years (65%) suggesting significant exposure to the issues faced by the department, however almost a quarter (24%), were also relatively 'new starters' that may not have experienced issues thought of as commonplace by others. The average time served of 6-8 years does still suggest that these results give an accurate representation of the issues experienced within the EBME department. Despite, time served not recorded during the qualitative interview process, presenting a data limitation, all of those interviewed appeared well experienced in the issues faced in their various roles.

Department Challenges

Undoubtedly the main challenge faced by the EBME departments raised in the collected data is in the location of equipment and it seems that the benefits offered by asset tracking systems are, as perceived to by those within the department, a potential solution to this key issue. The sampled PPM sheets support this providing evidence of many items missing maintenance and service due to the inability to locate them in a timely manner as well as also demonstrating a rudimentary approach to equipment management in need of updating. This is further substantiated in the prevalence of the words cloud terms, particularly *Time*, *Maintenance*, *Service* and *Find,* in the content analysis and are a good representation of the themes that were raised in both the qualitative and quantitative data.

Whilst the location and effective management of equipment is important in all hospitals, the act of transporting loan or replacement equipment to island locations when equipment cannot be located or has failed has been cited as a key reason for an increase in operational costs, which appears to align with the key themes highlighted in the literary review. However, with regard to how often challenges were faced locating equipment for service engineers or for field service corrective action, the mean response of survey respondents was rarely. This seems contrary to the qualitative data collected which cited that these were two key reasons why asset tracking would be a benefit. One explanation may be that these types of issues are dealt with more senior members of the EBME departments but, other than anecdotal evidence, there was little to support this claim and further research would be required to establish this.

Amongst the senior members interviewed, asset tracking also appears to be considered a risk reducing measure, not only in the swift removal of equipment affected by field service notices from circulation but also improving levels of resilience and alleviating pressure on clinical teams to concentrate on patient care.

Cost Savings

In addition to the potential savings in labour hours shown in the previous analysis, the evidence suggests that there is a perception that asset tracking would provide further cost saving benefits beyond that of simply saving engineers' time. It was felt that asset tracking would mitigate against the need for service engineer revisits and the expensive transportation of loan items as replacements when equipment cannot be found. In addition, belief is that better management of equipment through the use of asset tracking could alleviate a culture of ownership, encouraging the sharing of equipment and improving the level of equipment utilisation. While resilience will always be a factor due to the remoteness of island-based EBME departments, it was felt that the technology could eventually lead to the ability to reduce the amount of equipment required by the organisation allowing budgets to be better spent elsewhere. However, other than a perception

amongst participants there was little evidence available to substantiate these claims.

Mitigation

It seems the major benefits of asset tracking lie in the real time visualisation of equipment, assistance in locating items and the ability to capture device service information, however, these are issues faced by all hospitals not just those based in remote areas. Though this research has demonstrated a potential cost saving in reducing labour hours in searching for equipment, rather than tackling the challenges of geographical isolation directly, for island-based EBME departments, perhaps the main benefit of asset tracking is in mitigating the higher operational costs associated with their locations. From this perspective, the improved level of effective equipment management that asset tracking brings may provide a real benefit to healthcare organisations that are geographically removed from the mainland by minimizing unnecessary operational expenses and maximizing operational efficiencies.

Positive Perception & Support

The evidence in the collected data appears to show a positive perception towards the implementation of an asset tracking system within the island-based EBME departments examined. The main rationale for this seems to lie in the anticipated improvement to working efficiencies and a potential for cost savings already mentioned to combat the many challenges that are attributed to the department's geographical location. However, while there is much evidence in the data that supports an asset tracking system, the data suggest that it is likely to do more for general equipment management issues rather than those attributed specifically to island-based challenges.

Limitations

Though this research sought to identify perceptions with specific regard to the benefits asset tracking may bring to island-based EBME departments, this has made for a narrow sampling scope of participants, many known to the researcher. This, in addition to the use of forced response questioning, means that cognitive biases such as acquiescence bias, courtesy bias, halo effect and demand characteristic biases cannot be completely ruled out. Also, though the use of Likert scales has afforded this forced response, its ordinal data offers little in the way of discerning variations in the data set (Akman, 2023).

Whilst two separate island-based EBME departments were approached for participation, both display an affluence not common to all jurisdictions and as such may not provide a universal reflection of experiences and, with hindsight, inclusion of a mainland organisation may also have provided a useful comparison. Furthermore, the involvement of other stakeholders such as clinical teams, hospital stores and external service engineers may have provided additional insight into the role asset tracking may play in assisting offshore healthcare organisations.

Other areas of inadequacy include little available literary research on EBME challenges and insufficient cost-benefit information, which doesn't account for ongoing costs of the investment. These factors, as well as those above, may affect the generalisability of this study and as such demand further research be undertaken.

Summary & Conclusions

Systematically reviewing literature on the subject of island-based EBME departments, while not specific, has established two relevant themes in the isolation that island-based EBME departments are faced with and the higher operational costs that they endure. In addition, it has highlighted the various advantages and benefits surrounding asset tracking technology within healthcare environments.

In spite of several limiting factors, much of the empirical research undertaken to corroborate these findings by identifying perceptions of island-based EBME challenges and the impact asset tracking may have on them, aligns with and supports the existing literature as well as exposing an appetite for implementing asset tracking within the departments, providing answers to the original research questions.

The research has shown that, while asset tracking has the potential to alleviate many of the general issues experienced by healthcare organisations, the real-time visualisation of equipment may also provide solutions to some of the challenges faced specifically by island-based EBME departments such as optimising visiting service engineers time and mitigating expensive transportation and revisit costs.

Though implementation challenges such as resistance to change, training, available resources and ongoing support and maintenance have been acknowledged, there is an overwhelming perception that asset tracking would deliver improved equipment management, relieve certain island-based financial pressures as well as encourage a culture of shared resources and better utilised equipment.

Despite this wide support for the technology and a strong view that it will deliver solutions, it is still unclear how these benefits will be measured. Scrutiny of KPI's through reduction in labour hours, improved utilisation of equipment and increase productivity are claimed however, whilst a simplistic calculation of potential labour cost savings has been offered, these savings, as well as those related to avoidance

of service revisits and potential reduction in equipment have been largely unquantifiable in this research.

Recommendations

Despite, meeting the objectives with regard to operational challenges and potential benefits of asset tracking implementation, this research has fallen short on those related to cost-benefit and suggestions for implementation and further research, as listed below, is recommended to quantify the tangible benefits the technology is anticipated to bring to island-based EBME departments.

Recommendation	Explanation
Quantify labour savings	Quantify potential labour savings and establish measurable KPI's for implementation
Quantify Third Party Savings	Collect further information to support the potential savings made from avoidance of service revisits.
Quantify reduced equipment savings	Collect further information to support the potential savings in reducing the amount of required equipment whilst maintaining the resilience required for island-based healthcare organisations.

Figure 22 - Recommendations.

Conclusion

In conclusion, and with regard to the original research question, it seems that asset tracking has the potential to offer considerable benefits to island-based EBME departments in the day-to-day management and utilisation of medical equipment but, and perhaps more importantly, the improved visualisation and efficiency the technology offers could provide the potential to off-set the higher operational costs associated with their isolation and geographical remoteness. However, further investigation is required to provide a clearer understanding of what these potential financial savings may look like. In addition, while the generalisability of this research is uncertain, it is felt that the research adds valuable information to the body of knowledge on efficient EBME department management particularly regarding the challenges surrounding isolation and better informs third party service providers of considerations when dealing with island-based organisations.

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Appendix A – Literary Review

The benefits of asset tracking as a tool for improved management of medical equipment have been widely documented however, these benefits don't come without significant financial investment, which for smaller organisations can be difficult to justify. This is particularly the case for small, isolated island healthcare organisations and this literature review will seek to establish the challenges that these settings face in managing medical equipment and if asset tracking as a solution is a worthwhile investment.

The following keywords have been used during literature searches: Island-based, healthcare, geographically isolated, asset tracking, remote.

Whilst some core day to day primary and emergency care services must be provided for island populations (Gould and Moon, 2000, p. 1082), those with low population levels do not justify the provision of high order services (Royle, 1995, p. 257). However, Gould and Moon (2000, p1085) argue that this is not true for all islands and more affluent populations mean health departments can provide some services that would be uneconomical in otherwise comparable locations. Therefore, where these provisions are provided it is fair to assume that the relevant supporting departments also exist, namely EBME at some level.

The literature tends to focus on 2 main challenges to island healthcare, being isolation and cost. As well as making island living more precarious for an aging population (Bates et al, 2019, p.182), Hotchkiss (1994) says that islands have to pay more to achieve the same level of healthcare provision due to a dis-economy of scale, an idea expanded on by Gould and Moon (2000) saying that these locations are subject to an 'island-penalty' due to their small size and isolation from the mainland arising from increased cost of supplies and services due to overseas transportation. Whilst the available literature does not specifically deal with island based EBME departments, it is reasonable to assume that these same challenges can be attributed to this area.

Much of the literature on island healthcare is somewhat dated, however the issue of isolation and high cost seem to hold true with Kelman (2021, p.110) saying that during the pandemic some island jurisdictions lacked the health systems and equipment to deal with it effectively.

Effective maintenance of medical equipment is crucial and both Vatn et al (1996) and Jardine et al (1997, p109) agree that the goal of maintenance should follow an economic approach to maximise personal safety whilst minimising operational costs. Aruna et al (2018, p.69) agrees saying EBME equipment management must maintain equipment in a cost-effective manner. In addition, the MHRA (2021) say that medical equipment should, amongst other things, be adequately deployed, tracked and utilised as well as addressing risk management concerns such as field safety notices.

Considering that Aruna et al (2018) reports manual management of medical equipment leads to increased human error and lapse of preventative maintenance and Yoo et al (2018, p1) say that real-time location asset tracking systems (RTLS) has been used to manage assets efficiently in other industries and their implementation in hospitals has been shown to deliver improvement in both work processes and cost reduction, it seems that asset tracking technology may have the potential to meet some, if not all, of these requirements.

Antree (2017, p.2) concurs saying that asset tracking technology provides fast and accurate capture of asset data and location and has been proven to be highly effective. Although this source is a white paper it highlights, the two main drivers behind asset tracking implementation: locating medical devices and satisfying clinical, regulatory and financial governance. It also references the 2016 Carter report that says that real time monitoring is found in the best performing hospitals around the world to improve quality and efficiency performance (Carter, 2016, p.7). Carter (2016) goes on to recommend that all hospitals should have a fully integrated digital information system including asset tracking where appropriate.

However, Janz et al (2005, p.141) argues that although asset tracking has been praised for its potential applications, users should be cautious that this doesn't raise any unrealistic expectations as the unique characteristics and processes of different environments will require proof of application at some level.

This literature review has identified that there is a gap in the research with regard to the potential benefits asset tracking technology could specifically bring to healthcare organisations that are geographically isolated. However, it has established that there are challenges such as isolation and high operational costs associated with island-based healthcare organisations and these challenges seem to align with many of the prospective benefits that asset tracking technology purveys.

Appendix B – Interview Questions

The questions that follow make up the open-ended interview questions that was delivered to 5 senior members across 2 island-based EBME departments during the qualitative data collection.

1. Can you describe your role and responsibilities within the EBME department?

2. How would you characterize the size and scope of your EBME department?

3. What are the primary challenges to managing medical equipment within your EBME department?

4. Can you identify any specific challenges faced by island-based EBME departments in managing medical equipment?

5. What are the main difficulties faced with regard to keeping track of medical equipment around the hospital?

6. As an island-based hospital, how does your geographical location impact the management of medical equipment within your EBME department?

7. Do you implement a planned preventative maintenance (PPM) regime for medical equipment?

8. Does ineffective equipment management ever impact on planned preventative maintenance (PPM)?

9. How do you respond to Field Safety Corrective Actions for medical equipment?

10. Does ineffective equipment management ever impact on Field Safety Corrective Actions?

11. Are there any specific financial implications to managing medical equipment in an island-based hospital?

12. Is medical equipment ever serviced by visiting manufacturer service engineers?

13. Does ineffective equipment management ever impact on the work of visiting manufacturer service engineers?

14. How do you believe the implementation of asset tracking would impact medical equipment management within your EBME department?

15. Can you see any potential benefits with regard to medical equipment management by implementing asset tracking?

16. Can you see any potential benefits with regard to resource optimization by implementing asset tracking?

17. Can you see any potential benefits with regard to equipment maintenance by implementing asset tracking?

18. Can you see any potential issues with regard to the implementation of asset tracking?

19. What are the benefits of implementing an asset tracking system to an island-based EBME department?

20. Can you see any specific benefits with regard to the operational costs?

21. Can you see any specific benefits with regard to key performance indicators (KPI's)?

22. Overall, do you believe that asset tracking could be a worthwhile investment to the EBME department in tackling the challenges you have mentioned?

23. How would you plan on measuring any return on investment of any asset tracking implementation?

Appendix C – Survey Questions

The questions that follow make up the online survey that was issued to 28 EBME engineers during the quantitative data collection.

1. **To the nearest year, how long have you worked in the EBME department?**

0 – 2 years	
3 – 5 years	
6 – 8 years	
9+ years	

2. **How would you rate the effectiveness of medical equipment management within your department?**

1	2	3	4
Very Ineffective	Ineffective	Effective	Very Effective

3. **What are the primary challenges with regard to medical equipment in your day-to-day tasks?**

Difficulty in locating equipment	
Restricted access to equipment	
Issues repairing equipment	
Sourcing spare parts	
Other	

4. **How often do you face challenges in locating medical equipment for repair or service?**

1	2	3	4	5
Never	Rarely	Monthly	Weekly	Daily

5. **How often do you face challenges in locating equipment for visiting service engineers?**

1	2	3	4	5
Never	Rarely	Monthly	Weekly	Daily

6. **How often do you have to locate equipment for field safety corrective action such manufacturer software upgrade or return to manufacturer?**

1	2	3	4	5
Never	Rarely	Monthly	Weekly	Daily

7. **On average, how long would you say you spend looking for equipment per week?**

1	2	3	4	5
Never	Less than an hour	1 hour or more but less than 3 hours	3 hours or more but less than 5 hours	5 hours or more

8. **Do you feel that an asset tracking system would help in reducing the time spent looking for equipment?**

Yes	No

9. **How often do you require loan equipment to be shipped over to temporarily replace faulty medical equipment?**

1	2	3	4	5
Never	Rarely	Occasionally	Frequently	Extremely frequently

10. Do you believe that implementing an asset tracking system would improve the efficiency of managing the medical equipment within your department?

1	2	3	4
Strongly Disagree	Disagree	Agree	Strongly Agree

11. Do you believe that implementing an asset tracking system would improve the efficiency of carrying out planned preventative maintenance (PPM) within your department?

1	2	3	4
Strongly Disagree	Disagree	Agree	Strongly Agree

12. What do you believe is the <u>main</u> benefit that asset tracking software could bring to your department?

Improved maintenance scheduling	
More efficient location of equipment	
Better inventory management	
Better allocation of equipment resources	

13. What would be the <u>main</u> challenge to implementing asset tracking software within your department?

Increased administration activities and ongoing support	
Changing operational procedures	
Software Training	
Using the system after implementation	

14. How confident are you that asset tracking implementation of an asset tracking system would prove successful?

1	2	3	4
Not confident at all	Not so confident	Confident	Very confident

15. Do you believe that the benefits of introducing an asset tracking system would be worthwhile?

1	2	3	4
No, definitely not	No	Yes	Yes, definitely

16. Please comment below if you would like to expand on any of your answers given above?

Appendix D – PPM Sheet Sample

Fig.23 shows a sample of a past PPM sheet with several assets that have not been serviced due to an inability to locate the equipment. Some details have been redacted for confidentiality purposes.

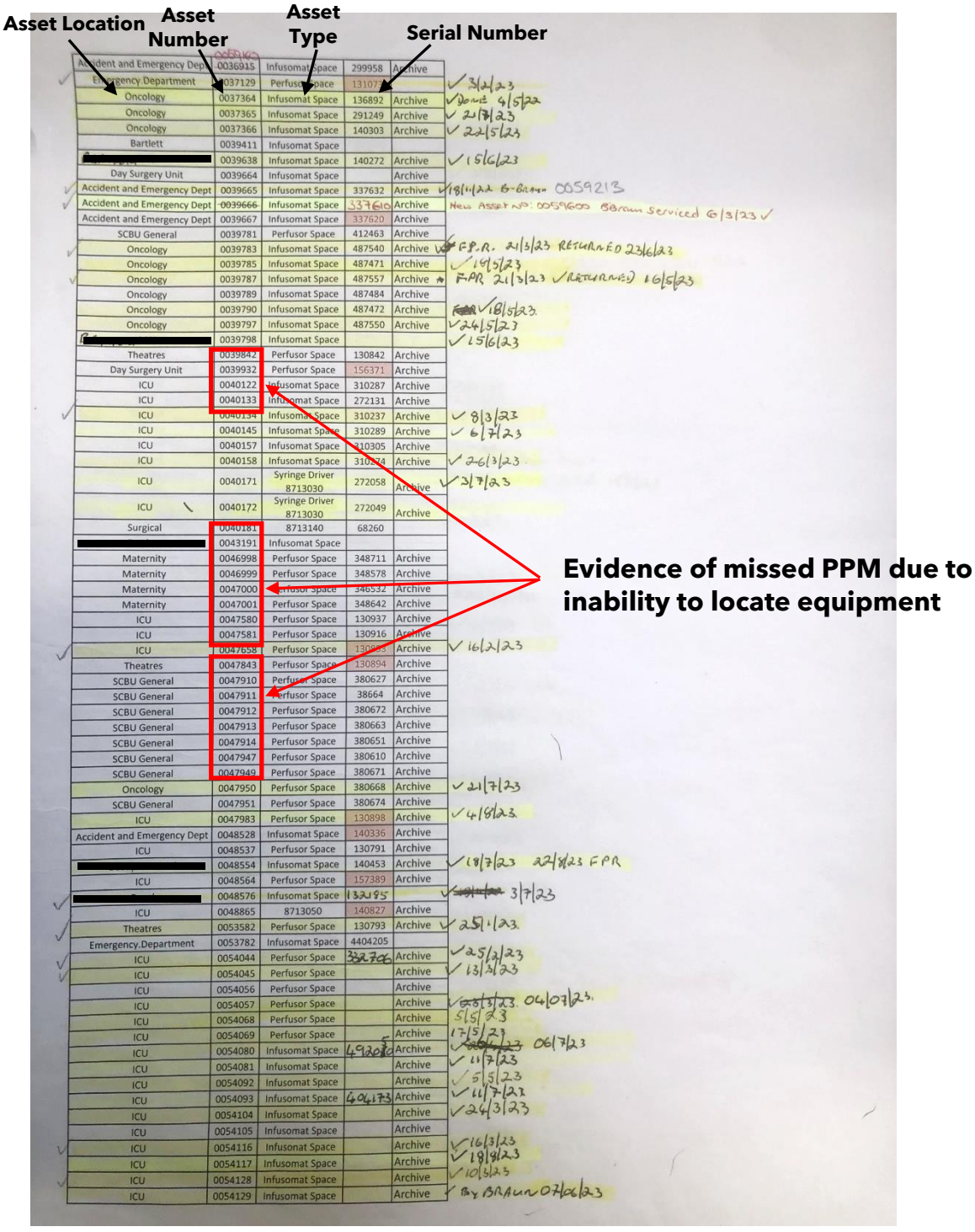

Figure 23 - Past PPM Sheet for 2022/2023

Appendix E – Content Analysis

Fig.24 illustrates a word cloud content analysis of the collected qualitative data.

Figure 24 - Content Analysis Word Cloud using freewordcloudgenerator.com (2021)

Appendix F – Thematic Analysis Identified Themes

Fig.25 illustrates the thematic analysis process and the subsequent main themes that were identified.

Coding	Emerging Themes	Main Themes	Final Themes
Lack of Local Resources	**Reliance on Third Parties**	**Reliance on Extraneous Resources**	**Reliance**
Reliance on Visiting Service Engineers			
Return to Manufacturer			
Reliance on Loan Equipment	**Reliance on Supporting Resources**		
Reliance on Spare Parts/Equipment			
Equipment Ownership & Availability	**Equipment Availability & Utilisation**	**Resource Utilisation**	**Equipment Management & Utilisation**
Equipment Utilisation			
Reduce Amount of Equipment			
Medical Equipment Procurement Issues	**Procurement Issues**	**General Operational Issues**	
Departmental Issues	**Operational Issues**		
Difficulty in locating Equipment	**Inadequate Equipment Management**	**Equipment Management**	
Lost Equipment			
Transportation Issues & Costs	**Logistical Challenges**	**Island Operational Challenges**	**Island Challenges**
Geographical Location			
Lost Time & Resources	**Operational Inefficiencies Attributed to Geographical Location**		
Additional Costs			
Additional Labour & Maintenance			
Financial Challenges			
Support For Asset Tracking	**Benefits and Challenges of Asset Tracking Implementation**	**Asset Tracking Perceptions**	**Asset Tracking Advantages**
Challenges to Implementation			
Safety	**Operational Risks**	**Risk**	
Field Safety Notices			
Operational Risk			
Lack of EBME Dept. Governance			

Figure 25 - Thematic Analysis

Appendix G – Statistical Analysis

Table 6 illustrates how the Likert scale answers have been interpreted using different scales for 4-point and 5-point questions (fig.26).

Table 6 - Statistical Analysis of Likert Questions

	To the nearest year, how long have you worked in your EBME department?	How would you rate the effectiveness of medical equipment management within your department?	How often do you face challenges in locating medical equipment for repair or service?	How often do you face challenges in locating equipment for visiting service engineers?	How often do you have to locate equipment for field safety corrective action, such manufacturer software upgrade or return to manufacturer repair?	On average, how long would you say you spend looking for equipment per week?	How often do you require loan equipment to be shipped over to temporarily replace faulty medical equipment?	Do you believe that implementing an asset tracking system would improve the efficiency of managing the medical equipment within your department?	Do you believe that implementing an asset tracking system would improve the efficiency of carrying out planned preventative maintenance (PPM) within your department?	How confident are you that implementation of an asset tracking system would prove successful?	Do you believe that the benefits of introducing an asset tracking system would by worthwhile?
	Q1	**Q2**	**Q4**	**Q5**	**Q6**	**Q7**	**Q9**	**Q10**	**Q11**	**Q14**	**Q15**
Mode	4	2	4	2	2	3	3	4	4	4	4
Median	4.00	2.00	4.00	2.00	2.00	3.00	3.00	4.00	4.00	3.00	4.00
Range	3	3	3	3	2	3	3	3	3	2	1
Mean	3.10	2.43	3.86	2.48	2.52	3.00	3.19	3.48	3.57	3.38	3.76
Average Likert Response	**6 to 8**	**Ineffective**	**Weekly**	**Rarely**	**Rarely**	**>1hr but <3hrs**	**Occasionally**	**Strongly Agree**	**Strongly Agree**	**Very Confident**	**Yes, Definitely**

4-point questions	5-point questions

4-point interpretive scale			
$Range = Highest\ Value\ Option - Lowest\ Value\ Option = 4 - 1 = 3$ $Interval = \frac{Range}{No.of\ Options} = \frac{3}{4} = 0.75$	**1**	1.00	1.74
	2	1.75	2.49
	3	2.50	3.25
	4	3.25	4.00

5-point interpretive scale			
$Range = Highest\ Value\ Option - Lowest\ Value\ Option = 5 - 1 = 4$ $Interval = \frac{Range}{No.of\ Options} = \frac{4}{5} = 0.8$	**1**	1.00	1.79
	2	1.80	2.59
	3	2.60	3.39
	4	3.40	4.19
	5	4.20	5.00

Figure 26 - Interpretive scale to find average Likert response.

The calculated mean from Table? above can be used to determine the average Likert response using the relevant interpretive scale.

For example, a mean of 3.86 for question 4 falls between 3.40 and 4.19 on the 5-point interpretive scale and provides an average response corresponding to option 4, which in this case relates to the answer 'Weekly'.