An investigation into the use of Video and Performance Analysis Systems and Design in Cycling New Zealand and the Team Pursuit discipline.

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Abstract

The aim of this thesis was to investigate the effective use of video and performance analysis (PA) systems in the Track Cycling Olympic programme in New Zealand. The thesis focused on the Team Pursuit discipline in the Track Cycling endurance squad and used coach driven performance objectives and questions. A Design Science Research (DSR) approach was used to provide a strong framework for this research. The DSR framework follows the structure of problem identification, objectives of a solution, design and development, demonstration, evaluation and communication of findings. This framework was used alongside the PA multidisciplinary approach from Glazier (2010), which focuses on the technical, tactical, physical and psychological aspects of performance. A range of ethnographic data collection techniques, including observation, reflective notes and informal interviews, were applied to gather information and feedback on changes made to PA. The initial findings of the research were that current Cycling New Zealand PA systems and design could not be used to meet the needs of the Team Pursuit performance objectives. Changes to the systems and design PA artefact took place with hardware and software being further explored to be able to meet these needs. From the changes made PA became more performance focused and started to move closer toward a multidisciplinary approach to PA. Future recommendations, taking into consideration, cost and timing, were put in place to be able continue the DSR research process.

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Table of Contents

List of Figures

List of Tables

Thesis Organisation

This thesis consists of six different Chapters. The first chapter is an introduction into Track Cycling and provides context for the study. Chapter two provides a review into the current literature that exists around the thesis topic and research objectives. The third chapter is a technical report, which is built to present to Cycling New Zealand on the thesis topic. This chapter consists of an executive summary, introduction and literature review, a Design Science Research (DSR) method of producing results, discussion, strengths and limitations of the study and a concluding paragraph. Chapter four is a full thesis discussion and conclusion that focuses on the model chosen to conduct the research, the findings and comparing these to literature, strengths and limitations, practical recommendations and future directions with the research. The following two chapters are a reference list and appendix.

Formatting

The referencing style and formatting used throughout this thesis follows the American Psychological Association (APA) 6th edition. The approach was used in alignment with the requirements set out by the Otago Polytechnic for the Masters of Applied Science.

Chapter One: Introduction

The Track Cycling discipline of Team Pursuit requires tactics and drafting techniques that need to be performed under great levels of fatigue (Faiss, Maier, & Sigrist, 2017). Like many Olympic sports, Track Cycling also requires a high level of performance physically and psychologically. The Olympic games is the pinnacle event for Track Cycling, with Team Pursuit seen as one of New Zealand's main Track Cycling focuses at the Olympic games in 2020 and has been for a number of Olympic cycles. The athletes have access to a extensive support systems to help them achieve their Olympic performance goals, including Coaches, Physiotherapy and Medical, Nutrition, Psychology, Sports Science, Mechanical equipment support, Athlete Life and Performance Analysis (PA). These support services and staff are important to the Track Cycling program and help with providing information to inform decisions in all areas of performance. Working within a high performance/world class sport environment has been identified as a highly stresssful occupation (Gould, Gruinan, Greenleaf, & Chung, 2002). Everyone working within this environment needs to become able to cope with high pressure and a constantly changing environment. Each area of sport science needs to demonstrate a real impact on performance. The funding received for the sport is based upon competition performance, medals won and medallists developed (Bryant, et al. 2018). The field of sports science is very technical, challenging applied scientists to apply new knowledge and embrace new technology (Giblin, Parrington, & Tor, 2008).

The pursuit of marginal gains (1% improvements in training or performance) is essential in improving overall performance against quality opposition and can have a big impact on the success of a high performance program. Marginal gains can be defined as an accumulation of a number of small gains that becomes a result in a larger gain in overall performance (Hall, James, & Marsden, 2012). The 1%, or the marginal gains, in cycling usually consist of technology-based approaches, such as bike frame, wheels, clothing and technology that enables collection and analysis of real time performance data. (Hall, James, & Marsden N. 2012). PA is a relatively new area of sport science which athletes, coaches and sport scientists are using to find their performance advantages. Establishing a strong PA system and process to compliment performance objectives and the feedback process, for the New Zealand Team Pursuit squad, is crucial heading forward toward the next Olympic games. The information, included with the other support disciplines, will help provide a broad view of performance and help better inform performance decisions.

PA is a broad term that covers a number of areas in sports science, including notational, biomechanical, physiological and psychological (Glazier, 2010; Carling, Collins, & Wright, 2014). In the past thirty years, it has attracted a great deal of research within multiple sports (Bampouras, Cronin, & Miller, 2012). PA can be efficient and effective in providing appropriate, comprehensive and objective feedback to coaches and athletes.

It can be fundamental to learning and development (Butterworth, Cropley, & O'Donoghue, 2013). While notational analysis is the main discipline in PA, there has been much debate over which areas of sports science that are considered part of the PA discipline (Barlett, & Bussey, 2012; Glazier, 2010). Glazier, (2010) described PA as multidisciplinary, involving four different areas of science, technical, tactical, physical and psychological. His viewpoint created debate around some of the main issues inhibiting progress in PA. These areas are concerned with analysing and evaluating performance for the benefit of the athlete. Issues common between notational and biomechanical analysis include optimising feedback to both coach and performer to improve performance (Bartlett, & Hughes, 2002). This could also be said for the physical and psychological areas of sports science.

There has been research covering each of the multidisciplinary areas separately in sport, with the combination of notational and physical analysis research being most common. An example of this approach can be seen in the work of Matsushigue, Hartmann, and Franchini, (2009) and Chaabene et al. (2014), who examined the physiological responses of Taekwondo and Karate athletes, alongside time motion analysis, combining physical and notational analysis in research. other researchers have explored video-based feedback and psychological factors in sport. Using questionnaires or interviews, researchers have combined what is seen as PA and psychological factors together (e.g. Cushion, & Groom, 2005; Harwood & Middlemas, 2017). This research has examined the delivery of video-based feedback from a psychological perspective and the perceptions of both coaches and athletes regarding the effectiveness of this technology. Technical and tactical aspects of sport have been investigated in team and individual settings. These studies examine outcome measures, tactical skills in relation to technical movements, the role that playing age and experience has on technical and tactical aspects and injury risk from a technical perspective has been explore by a number of researchers (e.g. Gabbett, & Ryan, 2009; Kolmann, Kramer, Elferink-Gemser, Huijgen, & Visscher, 2018; Wheeler, Wiseman, & Lyons, 2017). These examples above demonstrate how areas of sport science can use research individually or paired with another area of sports science to analyse performance and gather information in sport. It is argued that combining these approaches into a multidisciplinary approach could help to provide greater depth to the feedback process for coaches, sports scientists and athletes. In an individual sport such as Track Cycling, coaches can draw on all fields of sports science to analyse performance, including technical, tactical, physical and psychological areas.

There are multiple approaches using PA within different sports to compliment feedback for coaches (Corley, et al., 2015). PA provides objective data to inform and support the coaching process and is a integral tool within the coaching process by helping to provide effective and accurate feedback (Byrant, James, Nicholls, & Wells, 2018). PA serves as a function to provide feedback, help identify areas of improvement, evaluate specific areas of performance and operate as a selection mechanism of coaches and athletes (Bartlett, & Hughes, 2008). The key support staff that interact with PA in Track Cycling are the physiotherapist, sports scientist and coach. PA brings together notational and biomechanical analysis of performance, and provides the scope and theoretical concepts from other disciplines, such as physiology and Psychology (Glazier, 2010). Multiple areas of sports science can use video to analyse performance including physical conditioning, physiology, psychology and nutrition were all areas (Wilson, 2008). Technique PA is a sub-discipline of PA, and is used most commonly with individual sports skills, such as Track Cycling, rather than wider aspects of sports and games where strategy and tactical play are influencing factors (Hughes & Franks, 2008). Working in Track Cycling, there is a need to combine the technical analysis with the wider range of sports science disciplines into the PA system and process to benefit coaching feedback.

The introduction of technology in sport has advanced training and performance through the use of tracking devices, statistical tools and visual interactive demonstrations through video replays (Gilbert, & Thomas. 2016). The application of video and computer technology in sport and the use of preview/review sessions into training programmes has led to the widespread use of PA by coaches, athletes and other sports scientists. PA has become increasingly accessible to coaches and sports teams/individuals, particularly the use of modern PA software such as Sportscode™ and Dartfish™ (Atkins, et al. 2012; Liebermann et al, 2002). PA is a valuable asset in the feedback process (Cushion, & Mackenzie, 2013; Drust, 2010) and is one of the most important variables affecting learning and performances of skills in sport (Franks & Hughes. 2008). In the coaching process, feedback is critical and helps achieve the ultimate aim of enhancing future performance. While there is literature that determines how PA and feedback are used and improvements that could be made in sport (Carling et al., 2014; Corley, et al., 2015), few studies have implemented the research recommendations in the applied setting, such as Track Cycling. There is a clear gap in literature surrounding the design of the systems and processes of PA within real-world applied sport environments. Design Science Research (DSR) is a method of research that focuses on creativity in the design and construction of artefacts that have a place in application environments (Chatterjee, & Hevner, 2010). DSR is a problem-seeking paradigm, which takes a technological view of an IT artefact, minimising attention to the shaping in an organizational context (Herfridsson, O'Rossi, Purao, & Sein, 2011). There are few studies that incorporate DSR into system design in sport and PA. The concept of DSR provides an opportunity for a strong framework to follow when designing a new system but this has had little attention in PA. The gap also extends to how Performance Analysts support and help provide critical feedback for athletes and coaches.

Study aims and objectives.

This study aims to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. It will specifically focus on the discipline of Team Pursuit. In particular, this study will aim to:

1. Investigate current PA systems and video use and evaluate the systems against PA literature.
2. Use a DSR methodology to implement changes to the current systems at Cycling New Zealand based off recommendations in the investiagation of video and PA systems.
3. Communicate changes and ways to improve to relevant staff. The findings will be presented to relevant staff in Cycling New Zealand as a technical report.

Chapter Two: Literature Review

The literature review will primarily draw on the areas of PA as a multidisciplinary approach, and will critically discuss the role of PA in sport and Track Cycling to date. Methodologies on systems and design will also be explored.

Cycling Performance and Literature.

There has been a body of research in the area of Track Cycling that covers a range of different aspects of sport science. The physical and physiological areas of Track Cycling are covered extensively. Physical and physiological track cycling research in the areas of energy systems, workload, strength and power capabilities and torque are common (e.g. Barrat, 2008; Craig, & Norton, 2012; McGuigan, & Vercoe. 2018; Mueller, & Schumacher. 2002). Other physical areas of Track Cycling that are investigated in research are eccentric and concentric training, as well as potentiation strategies (Abbiss, Macaky, & Penaillo, 2018; Fink, Foskett, Munro, & Stannard, 2017).

Examples of tactical and physical area of Track Cycling research have consisted of pacing stragies, Omnium scoring and decision making and sprint tactics of to lead or not to lead in individual sprint. (Corbett, 2009; Dwyer, Machman, Ofoghi, & Zalenznikow, 2013; Jones, Mauger, & Williams, 2011; McHale, Moffat, Scarf, & Zhong, 2014). Along with phyical and tactical areas, technical aspects of Track Cycling are also investigated in research (Blocken, Carmeliet, Defraeye, Hespel, Koninckx, Nicolai, & Verboven, 2013; Dijkshoorn, Heimans, Hoozemans, & Koning, 2017; Faiss, Maier, & Sigrist. 2017). Aerodynamic positioning is a large contributor to power loss in Track Cycling. There is research looking to optimize team efficiency by quantifying the effects frontal area has on power requirements in each team pursuit position. Faiss, Maier, & Sigrist (2017) explored the technical side of team pursuit and the technical transitions that occur between athletes. 96 athletes from 12 national Track Cycling teams were filmed during 77 team pursuit races in multiple international track-racing seasons. Transitions, or changes, (using the banks of the velodrome to keep momentum) allow riders to share time in the lead position, which is where riders are exposed to the highest aerodynamic resistance. This allows the riders to recover to some extent in the slipstream of their teammates (Faiss, Maier, & Sigrist 2017). Riders often spend 125 to 750m in the lead before transitioning. Transitions take place when the first rider leaves the front of the team pursuit and in the shortest trajectory uses the velodrome bankings to rejoin the team in last position. In this study, quantitative and qualitative variables were assessed (mean lead time, transition number, length duration, quality of start and end of change and distance from the third team mate). Findings included the lead time on the front of the team pursuit, which was found to be 18.1±

3.6 seconds, transition time moving above and below red line was around 3.3 ± 0.3 seconds and transitions started approximately 24.7 metres into the curve and lasted approx 78.3 metres. Combining these technical findings with the physical data of power output and the biomechanical views on a riders aerodynamic position could build a more in depth view on performance.

The literature within Track Cycling research, has primarily been focused on technical, tactical and physical aspects, covering three out of the four multidiscplinary areas of PA as debated by Glazier, (2010). Psychological is an area that has received significantly less attention. There is no research to date which has looked at how these areas of analysis can be used in combination to benefit feedback and information for coaches, through PA systems in Track Cycling.

Video Feedback and PA.

Feedback is one of the most important variables affecting learning and performances of skills in sport (Hughes et al, 2015). In the coaching process, feedback is critical and helps the ultimate aim of enhancing future performance. Recently, PA has evolved with more specialised analysts, who in specific contexts, are required to be an integral part of the preparation and feedback of information (O'Donoghue, 2010). Although coaches are the main source of feedback in daily training conditions, technologies aid the administration of feedback and enhancing augmented feedback. A trend that is occurring is the real time applications and devices that can deliver athletes, coaches and scientists with access to immediate data. The mode and the schedule of feedback are elements that are crucial in the process to improved sports performance. Making sure the feedback is not detrimental to the athlete but is the most effective and is based off the performance objectives (Giblin, Parrington, & Tor, 2008).

PA and specifically, video analysis systems offer coaches and athletes the opportunity to review performances numerous times post event. This reduces observer bias and increases the quality and accuracy of the information and feedback given (Hughes & Bartlett, 2008). Accurate and timely feedback is seen as critical in professional sporting environments and this has driven the uptake of PA systems (Groom & Cushion, 2011). Even the most basic feedback and information can be useful in the support of the coaching process (Carling, Collins, & Wright. 2014). A study by Groom, & Nelson (2004), using semi structured interviews to investigate video-based PA, found that video aided performance recollection, developed game understanding, encouraged player self-critique, gave the athletes a chance to reflect without emotions and improved player confidence. Jones, & Francis (2004) also had similar findings.

Workflows and PA in Sport.

Few studies have looked at how PA systems are designed and delivered to meet the needs of a specific sport. Corley, et al. (2015) conducted a systematic review of video-based methods for competitive swimming analysis. The review used an electronic database search to provide sufficient detail regarding equipment and experimental set up, relevant data regarding application of video in swimming and articles within the 5 year window before the article. The systematic review provided clear findings regarding video capture options used, camera selection and set up, camera configuration, data processing and feedback assessments in swimming. Recommendations were given from the information gathered in the review for a "best fit" application to swimming but the implementation of the recommendations was not present. It was found that the aquatic environment added to time, complexity and implementation of video analysis. It was also found that video allowed coaches to review, reflect and evaluate the development of athlete preparation, both qualitatively and quantitatively. Video has the adaptability to be applied in various feedback settings. Rapid feedback can be given via instant review, or video can be edited, processed and reviewed to provide feedback. Likewise, Carling, Collins, & Wright (2014) looked into the effective, practical and conceptual use of PA. How PA is used, how PA could be used and the growing constraints of PA were investigated. There was an importance identified in the continual development to provide meaning to how quantitative data is applied to PA and how information is effectively transferred to all parties involved in the PA process. Although these areas are key suggestions and important to investigate, like Corley, et al. (2015) the findings from the research were not implemented into a PA environment.

Research looking at coach perspective on workflow and the interaction they have with PA has been conducted by Bryant, James, Nicholls, & Wells, (2018). The research focussed on elite coaching use and engagement with PA within Olympic and Paralympic Sport. The findings pointed to a lack of research concerning the views of elite coaches toward the applied area of PA from an Olympic/Paralympic sport perspective. Findings also showed a lack of what the coaches value from a PA and feedback perspective. Developing an understanding of how the PA services could be implemented more effectively to benefit the coaching process is a considerable opportunity for applied practitioners.

Accurate and timely feedback, in all areas of sports science, is seen as critical in professional sporting environments and this has driven the uptake of PA systems (Cushion, & Groom, 2005). In a study conducted by Atkins, Jones, & Wright, (2012), elite professional and semi-professional UK coaches (n=46) were selected to complete an online-survey relating to their engagement with match, notational and technique analysis. A large percentage (75%) of those who took part found that the main factor limiting ability for feedback was the time taken to complete analysis and lack of time available. Although coaches are the main source of feedback in daily training conditions, technologies aid the administration of feedback and enhancing augmented feedback. Having a good system and design to help deliver the feedback in a timely matter is important. Bryant, et al. (2018) suggested that furthering research into elite coaches views on PA and developing an understanding on how these services could be implemented effectively to further benefit the coaching process for applied practitioners.

Not enough research in feedback and PA has looked into design and implementation of PA systems in elite sport. Despite the increase in flexibility with methods for feedback, coaches and sports scientists need to remain focussed on what material is provided back to the athletes (Giblin, Parrington, & Tor, 2016). This study allows an investigation into providing the most beneficial tools and material for coaches to provide feedback to athletes, in a multidisciplinary approach to PA.

There is limited research exploring systems and design approaches to PA in elite sport. Therefore the review below will focus on a different approaches to applying a systems design in a PA setting. This will allow for a model to guide implementation of suggested improvements to PA, and other support areas, in elite sport.

Systems Design

Systems and Design approach.

Systems and design research have many different areas of application, such as education, sociology, social psychology, philosophy, design and information systems research (Brannick, & Coghlan, 2005; Karmokar, 2013). Although these methods are well recognised and used in many different areas, minimal work has been done in the design and implementation of new systems and processes within PA in sport. Research methodologies have not yet been used to investigate and design PA systems and processes. Methodological approaches in this area have primarily included action research, DSR research and action design research. These approaches are reviewed below.

Action Research.

Kurt Lewin (1946) is considered the founder of Action Research (AR). Lewin introduced action research as a strategy to studying a social system. An attempt was made to make changes and emphasise the importance of client orientated attempts at solving particular problems (Gillis & Jackson, 2002). Lewin stated, “people would be more motivated about their work if they were involved in the decision-making about how the workplace is run”. The principles of Action Research have been applied to multiple fields of work over the years, including sociology, anthropology, social psychology, philosophy, feminist research and community based research. These have all been identified as areas that have used action research (Gillis, & Jackson, 2002). Action research (AR) uses theory and research intervention to solve immediate problems in organisations and is based on a collaborative problem-solving relationship approach to research between researcher and client (Brannicle, & Coghlan, 2005). Jarvinen (2007) stated that the contribution of AR as a discipline is in the practical concerns of people and goals of social science. AR focuses on the holistic impact on an organisation and the interaction of key future users, not just the build and development of a technology-based product (Brannicle, & Coghlan, 2005). Using the AR approach for the method of the thesis was considered. The people centred approach that AR adopts would potentially draw focus away from the technology design and build process. While the opinions and knowledge of people and organisations are important, the concept behind investigating the systems and design of PA in Cycling New Zealand offers the opportunity to bring the focus in on the products and technology rather than people.

Design Science Research (DSR).

A research method that adopts a similar approach to AR is Design Science Research (DSR). First conceived by Minder, Nunamaker, & Purdin (1991), DSR is found commonly in design, technology and information systems research. DSR is a paradigm that looks at engineering and sciences of the artificial (Simon, 1996). It is a problem-seeking paradigm, which aims to innovate ideas, practice, technical capabilities and products, where information science can be effectively and efficiently be accomplished (Karmokar, 2013). DSR focuses on creativity in the design and construction of artefacts that have a place in application environments (Chatterjee, & Hevner, 2010). Artefacts can be models, methods and constructs (Hevner, March, & Park, 2004). The process takes a technological view of the IT artefact, minimising attention to the shaping in an organizational context (Herfridsson, O’Rossi, Purao, & Sein, 2011).

The rigor of DSR is in the application of past knowledge to the research project to ensure innovation (Bragge et al., 2006). It is broken up into key sections, which differ throughout the range of models. However, a typical framework that DSR follows is (i) problem identification, (ii) objectives of a solution, (iii) design and development, (iv) demonstration, (v) evaluation and (vi) communication. Doyle, Neville, & Sammon, (2016) presented a case study on building an evaluation framework for social media enabled collaborative learning environments, demonstrating a solid structure for design research. Being product focused rather than participant focused is where DSR differs from action research. The focus being primarily on the design and build of an IT artefact, DSR would provide a good framework for PA systems. There are limited mental models or templates for researchers to evaluate against in DS research. Recgonising design research and its rigor have been limiting (Bragge et al. 2006) due to the limitations in mental models to follow. Another limitation to the DSR model is that it does not recognise the organisational context that can emerge with artefacts, which can be limiting for some researchers.

Action Design Research.

In more recent years a new method has been developed that combines both action research (AR) and DSR (DSR). Action Design Research (ADR) was designed by Herfridsson, O'Rossi, Purao & Sein (2011) as a way to merge the 'building' and 'designing' areas of DSR, with the organisational contexts of action research. ADR is a method that is comprised of four stages and seven principles within these stages. The four stages are 1. Problem formulation, 2. Building, intervention and evaluation, 3. Reflection and learning, 4. Formalisation of learning. ADR addresses problems in an organisational setting by intervening and evaluating the organisation. It also constructs and evaluates an IT artefact to address a class of problems identified (Bernhardsson, Haj-Bolouri, & Rossi, 2016). The purpose of the ADR was to accomplish limited separation of the design and build process of development from the organisational setting it will be used in. Herfridsson, et al., (2011) stated that the Build, Intervention, Evaluation (BIE) process should be in strong relation with the extensive participation by key stakeholders. ADR still draws on participant interaction, as well as design and build focus, which brings the similarities to both action research and DSR. ADR is a new method to systems research and therefore the use of the model is limited.

Summary of Design Science Approaches.

The need for a method to focus primarily on the design and build of an IT artefact to compliment the feedback and coaching process, leads toward the decision that DSR is more fitting for the PA process. Cycling New Zealand has a gap in knowledge on what products and systems are best to use in the area of PA. The needs of the "people and organisation" are understood but the right systems design to compliment what is already known, is needed. This study will therefore focus on product rather than an organisational context. Although feedback will be collated from coaches, to identify relevance of the PA systems and process build to performance objectives, the design and build will be the main focus for this research.

Chapter Three: Technical Report

TECHNICAL REPORT

AN investigation into the use of Video and Performance Analysis Systems and Design in Cycling New Zealand and the Team Pursuit discipline.

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Table of Contents

List of Figures

List of Tables

Executive Summary

Aim: The aim of this thesis was to investigate the effective use of video and performance analysis (PA) systems in the Track Cycling Olympic programme in New Zealand. The thesis focused on the Team Pursuit discipline in the Track Cycling endurance squad and used coach driven performance objectives to explore ways to improve PA in Cycling New Zealand.

Methods: A DSR approach was used to provide a strong framework for the research. The DSR framework follows the structure of problem identification, objectives of a solution, design and development, demonstration, evaluation and communication of findings. The DSR framework was used alongside the PA multidisciplinary approach from Glazier (2010), which focuses on the technical, tactical, physical and psychological aspects of performance. A range of ethnographic data collection techniques, including observation, reflective notes and informal interviews, were used to gather information and feedback on changes made to PA.

Results: The initial findings of the research were that current Cycling New Zealand PA systems and design could not be used to meet the needs of the Team Pursuit performance objectives set by the endurance coaches. Changes to the systems and design PA artefacts took place with hardware and software to be able to meet these needs. From these changes PA became more performance focused and started to move closer toward a multidisciplinary approach to PA.

Future Direction: Future recommendations, taking into consideration, cost and timing, were put in place to be able continue the DSR process. The continuation of the DSR process into PA in Cycling New Zealand will continue with work centred around the combining of physical, technical and tactical areas of Team Pursuit Track Cycling and a multidisciplinary collaborative environment.

Technical Report: The purpose of the technical report is to provide a condensed written document for Cycling New Zealand on PA in the track cycling environment. When presented to Cycling New Zealand, Chapter one and two of the thesis will be added to the technical report for context.

Methods

Context

The context for this study is the New Zealand Olympic Track Cycling programme focussed on the endurance discipline of Team Pursuit. Team Pursuit is an Olympic discipline that is held on an indoor Velodrome. Four team members compete over a 4000m distance to achieve the minimum possible time. Riders take turns riding in the front of the Team Pursuit line, allowing the other members of the team to draft closely behind and recover to a certain extent, in the slipstream of their team mates. Changes, or transitions, by the riders are made on the bankings at either end of the Velodrome, where the cyclist at the front swings up onto the banking and drops back down into fourth wheel position (Day, Jordan, Kroeger, Neumann, & Wagner, 2011; Faiss, et al., 2017). Team Pursuit is one of the main discipline priorities for Cycling New Zealand and is the leading event for both women's and men's endurance squads. The endurance squads train six days a week with multiple training sessions each day. In peak racing season (October – March) the athletes will be on the track training up to four days a week, with other training being based on the road or in the gym.

There are multiple areas of support that the athletes have access to help benefit performance in the Team Pursuit. This support includes the areas of coaches, physiotherapy and medical, nutrition, psychology, sports science, mechanical equipment support, athlete life and PA. All support is available on a daily basis and each area interacts with the athletes during training and racing. The Performance Analyst has a strong interaction with the disciplines of physiotherapy, sports science and coaches, combining knowledge to get a broad range of knowledge about performance. The analyst is responsible for assisting with training and racing video and key performance measurements to gather data on athlete performance. The Performance Analyst is also responsible for collating data, analysing, critically appraising and reporting key training and racing data and trends to coaches. The main area of support for the athletes comes from the coaches. Both endurance squads have a head coach and an assistant coach to work with. The coaches present the performance objectives and questions to support areas, such as PA, to gather staff expertise in helping inform performance decisions.

Role

During this study, I will be playing a dual role of performance analyst and researcher. It is a role that has many advantages, but could also lead to conflict in terms of responsibility and a loss of objectivity (Evans, & Jones, 2007). It is important to establish ground rules and planning with what role is required when, to ensure clarity is communicated to those involved. In this study, observations as a researcher will be made pre and post training of systems design and how PA can be applied in the training environment. During the hours of training, the role and performance analyst will be in place to work with athletes as coaches as needed. The introduction of informal interviews will be done with the coaches to allow objective information to be collected from another point of view in the environment.

Participants

The participants selected for this study were three endurance coaches working within the New Zealand Cycling environment. Two coaches work with the elite women endurance squad, and one with the elite men endurance squad. All endurance coaches were approached to take part in the study, with all agreeing to take part. The mean age of the participant coaches was 30.3 (Range = 28 – 34, SD = 2.6). Two out of the three have experience working in Track Cycling roles outside of New Zealand. The roles included international Track Cycling teams and regional level coaching. The coaches agreed to participate in the evaluation phase of the study, giving their feedback on the new artefacts introduced to the Track Cycling environment.

Study Design

The DSR process was chosen as a structured way of designing PA systems and processes to compliment the feedback and coaching process. This study will follow a model adapted from Bragge, et al., (2006), which can be seen in Figure 1 below. The model follows six stages, from problem identification through to communication of findings.

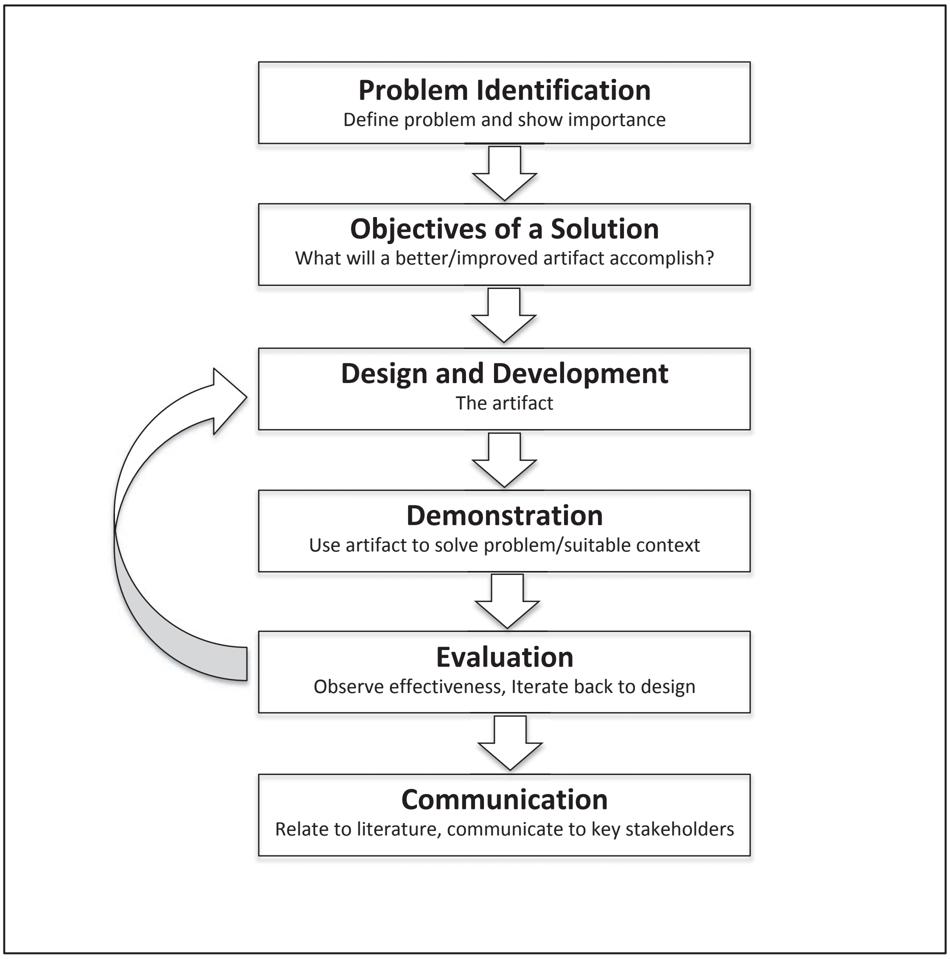


Figure 1. DSR process model adapted from Bragge, et al. (2006).

1. **Problem identification:** Identifying a current problem to practice and identifying a deficiency in the current systems. By clearly defining a research problem, a focus for the research is identified (Doyle, Sammon, & Neville, 2011). It is important in this stage to also justify the value a solution will have.
2. **Objective of a Solution.** Objectives should follow on from the problem identification and provide research focus (Peffers, et al., 2007). The objectives can be either qualitative or quantitative and eventually act as a metric at the evaluation stage of the project.
3. **Design and Development**. Create an artefact solution to the problem identified. Applying relevant technical and scientific knowledge to be able to design and development improvements. Artefacts can be constructs, methods, models or instantiations (Hevner, et al., 2004).
4. **Demonstration.** Using simulations, experiments and testing, demonstrate how the artefact works in the intended field of use.
5. **Evaluation.** Observe and measure how well an artefact supports a solution to the problem. Evaluate the artefacts use by comparing the artefact to the objectives set. Evaluation could include quantitative

measures such as budgets, observational feedback, user feedback, surveys or simulations. From here a decision can be made on whether to try to improve the effectiveness of the artefact by returning to the design and development phase of the DSR model. If satisfied with evaluation, communication will begin.

6. **Communication.** Communicate the problem and its importance to relevant researchers and audience. Discuss the artefact, the rigor of its design and the effectiveness of the DSR project. Reflect on limitations and further directions with the information gathered in the study.

Equipment.

During this research a range of different equipment was used in the area of PA. Hardware equipment used conducted of:

- Sony™ 4k Camcorders (FDR-AX53 4k Handycam).
- IP Cameras (Dahua™ DH-SD56230V-HNI Starlight PTZ Network Camera)
- HDMI, Ethernet and Thunderbolt cables and connections
- Blackmagic™ video capture devices
- Tripods
- Video decoder (Dahua™ Channel Smart 4k&H.265 Lite Network Video Recorder)
- Mac™ 15 inch Laptops

To be able to capture the speed and detail of track cyclists, specific camera specifications need to be used. Table 1 below shows the minimum specifications that are needed.

Table 2. Minium camera specifications for capturing Track Cycling video.

Minimum Camera Requirements						
Frame Rate	**Resolution**	**Shutter Speed**	**PTZ**	**Video Compression**	**Weight**	**Software Compatible**
50fps	720p	1/600	Yes	H.264/5	Below 4kg	Yes

Software used:

- Video capture software such as, Sportscode™ (Elite and Pro licenses), Dartfish™ (Pro), Piston™, Angles™, Quintec™, Nacsport™ and Kinovea™
- Microsoft Excel™

Informed Consent.

Before data collection occurred, each participant was given an information form on the research project and a participant consent form to sign if they agreed to be part of the project. All participants were assured through the information given that all information would be confidential and the participants could withdraw from the study at any time with the data on that participant also being removed. The Otago Polytechnic Ethics Panel, following a consultation from Kaitohutohu, also accepted ethical approval.

Data Collection.

The data was collected using three different methods through each of the DSR stages. A combination of ethnographic approaches were used such as participant observation, reflective notes and informal interviews. The aim of ethnographic data collection is strong, holistic insights into views and actions of people and the environment they work in (Hodges, Kuper, Reeves, 2008). This is through the collection of detailed observations and interviews. Ethnographic data collection has a tendency to work with unstructured data (Hodges, Kuper, Reeves, 2008). The use of participation, reflective notes and informal interviews as a data collection method allowed the holistic insights of those working closely to the performance analysis discipline in Cycling New Zealand to be considered in the study. The participant observation and reflective notes were an unstructured data collection approach, as well as the informal interviews, which followed a more guided conversation rather than a structured format. The three ethnographic data collection methods used in the study allowed for a holistic view on the performance analysis design in Cycling New Zealand. Participant observation allowed for the nonverbal expression of emotion and feelings to be observed by users of PA (such as athletes and coaches), the reflective notes allowed for an informal PA perspective on how the systems and design were having impact in the Cycling environment and the informal interviews allowed verbal feedback through the coaches.

Interviews.

The interviews were all kept to a limit of 20 minutes and were conducted in a location that provided limited distraction and easy one on one communication. An interview is among the most familiar strategies for collecting qualitative data. The type of interview that was conducted in this study was an unstructured interview. An informal conversational interview, or unstructured interview, is open ended, unstructured and the least formal of the interview approaches (Richie, Burns, & Palmer, 2005). An interview cannot be fully described as unstructured; however some are more of a guided conversation rather than a structured format (DiCicco-Bloom, & Crabtree, 2006). The interviews were conducted using an ethnographic approach, where notes were collected on observations in the environment. From here questions and information was formulated to give the interview some points of discussion.

The questions consisted of:

1. Are you happy with the new system and changes made?
2. Are the changes and new systems easy to use?
3. Does it help you to provide improved feedback on performance objectives?
4. Any suggestions for future improvements or changes?

Notes were taken in the interview to collect the information and points discussed.

Participant Observation.

Observational methods in research offer the opportunity to check for nonverbal expression of feelings, understand how participants communicate with each other, see time spent during specific activities and determine who interacts with whom. Participant observational methods allow researchers to develop a holistic understanding of information surrounding the study that is as objective and accurate as possible (Kawulich, & Barbara. 2005). In this investigation, the ability to observe athletes and coaches using new systems in PA and how this positively and negatively impacts feedback during training, gave more clarity on whether the systems and design changes and improvements are helping toward achieving the performance objectives. Observations were collected in note form of what was observed during training sessions and where the new PA systems or design were introduced to the environment.

Reflective Notes.

The ethnographic approach of reflective notes was used in data collection. Observations were made of coach use and athlete interaction of the systems and design in PA. This was recorded in reflective notes. These were written post training session. Notes were collected over a five month period when a new system/product was introduced or changed for the coaches or athletes. Observations were made when the product was first introduced and then after a few sessions of use. A template was created to keep the reflective notes consistent with questions and observations made.

Observations were also made from a PA perspective when a new product was changed or introduced. Information was collected on whether a product was easy to use and whether it addressed performance observations and questions from a PA perspective. These were also recorded as reflective notes.

Procedure.

Data collection was conducted in two rounds:

- **Round One**. In round one, investigation took place on the current systems and processes in Cycling New Zealand Team Pursuit using the DSR model and explored how these could be used in the most efficient and beneficial way. The objectives of round one were observed on how current PA systems were used daily in the Cycling New Zealand Team Pursuit environment. The process looked at the current systems and how they could be applied to improve information feedback for athlete and coaches, referring back to the multidisciplinary model from Glazier (2010) to look at whether the technical, tactical, physical and psychological areas of science were being introduced into the PA systems and processes. Performance objectives were a key driver in round one and were used as the framework of how PA systems and design could add value to the feedback process for coaches and athletes.
- **Round Two.** In round two, implementation of changes to the systems and processes were conducted. This was done through the investigation into improving software and hardware equipment in Cycling New Zealand PA. Round two looked at problems that were identified in round one and how a solution to these could be made. There was a focus on the technical, tactical, physical and psychological areas of PA in Round Two. Furthermore, there was a strong focus on performance objectives and aligning the new PA systems and design to be beneficial in helping achieve these objectives.

Data Analysis.

Notes were collected during the informal interviews. The notes were then transcribed in full post interview and confirmed with coaches as the correct points made. Trends between notes from the different coaches were combined and evaluated against observational notes collected during the introduction of new changes in PA to the environment. This helped to inform the decision on whether new changes or the introduction of new systems and design needed to occur. The interview and observational notes were also evaluated against the multidisciplinary approach from Glazier (2010) and whether the areas of technical, tactical, physical and psychological were addressed and how the four areas could be included more often in the analysis and feedback. The use of “critical friends” was used to help interpret findings and help guide final decision-making (Smith, & Sparkes. 2006). The research supervisors were involved in conversations to help with this, as the critical friends. The supervisors provided conversational help and feedback to keep the evaluation of the interviews on the right track. Once a decision was made around proceeding forward with changes or introduction of new systems and design, discussions with coaches and the high performance director took place to get final sign off on the project.

Results:

Round One of DSR Process

Following the DSR process the design and development into PA in Cycling New Zealand begun. The model below shows the process that occurred across the two rounds that were completed of the DSR process.

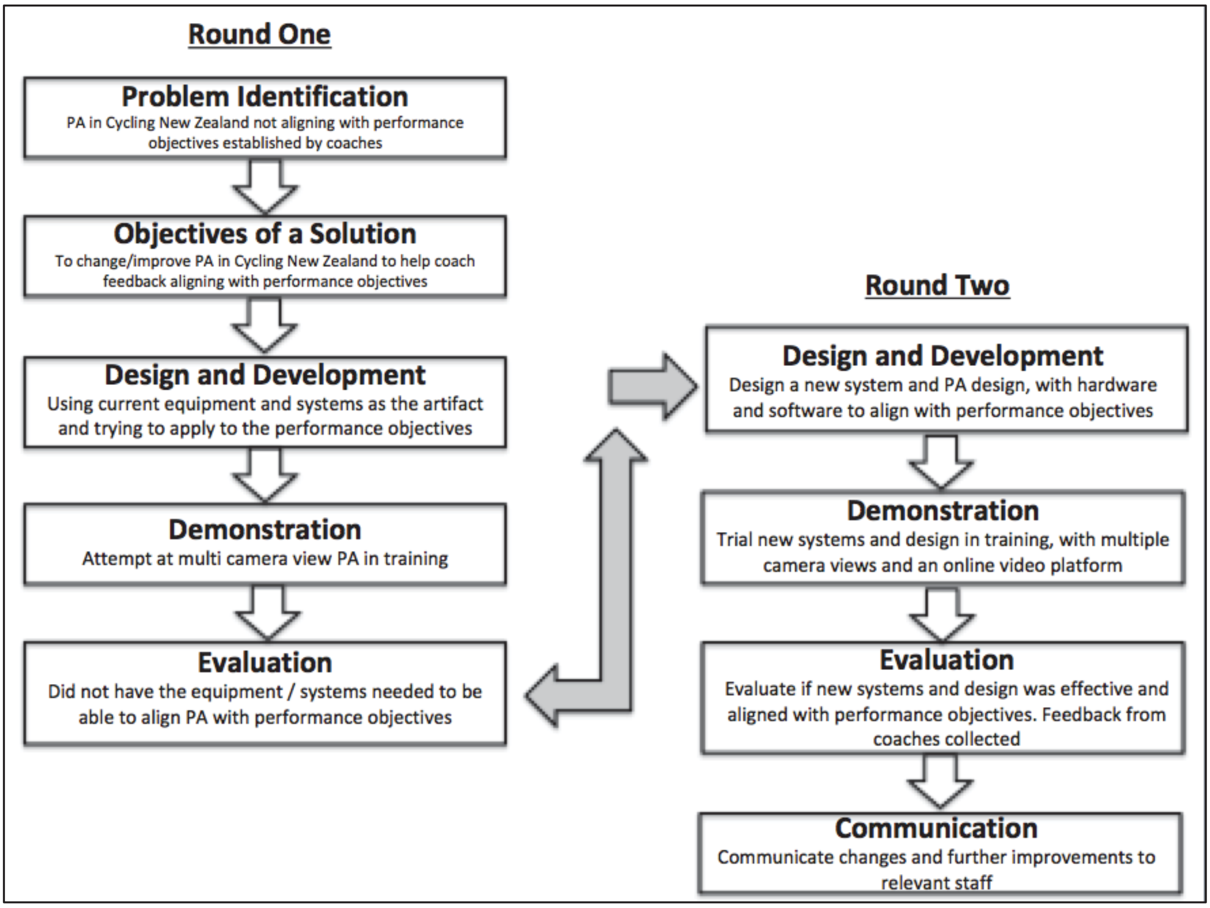


Figure 2. Showing the DSR process that occurred while investigating PA in Cycling New Zealand.

Phase One: Problem Identification.

Consultations with the Cycling New Zealand endurance coaches led to a greater understanding of what the key performance targets for the Team Pursuit squad. From this discussion a clear gap was identified in what was currently being analysed and what is needed in the future.

Areas of particular focus for Team Pursuit, that PA can enhance feedback in, are:

- Aerodynamic posture and maintaining this under load and fatigue.
- Evaluation of overall optimal following distance and line within the Team Pursuit to maintain formation throughout full effort
- Efficient Team Pursuit Changes

The coaches broke down team pursuit changes into further parts, which included:

- Where a Team Pursuit change starts
- Height and length of a Team Pursuit change
- Where a Team Pursuit change finishes and the ability to rejoin the Team Pursuit line within optimal distance and with accuracy (line formation)
- Being able to maintain aerodynamic positioning during changes throughout the Team Pursuit effort
- Finish of change, the power required to get back on the Team Pursuit line and whether that changes under fatigue
- Form under fatigue in aerodynamic postitioning – head coming up etc.

The points made above were used through the DSR process as the performance objectives. It was agreed that further investigation was needed to see whether the equipment that Cycling New Zealand PA currently had would be able to analyse key performance areas identified by the coaches or new equipment would be needed to achieve this. As well as technical aspects that needed to be analysed in depth, combining information on the physical and tactical components of endurance cycling and team pursuit needed to be considered.

Phase Two: Objectives of a Solution.

A solution in the investigation of systems and design in Cycling New Zealand allows the opportunity for more in depth analysis to be done and fed back to athletes. Being able to align PA with the needs of the Team Pursuit program, will allow more effective information to be present and help achieve performance objectives set by the coaches for Team Pursuit. The current systems and design does not address the performance objectives for the Team Pursuit and the overall PA feeedback in Cycling New Zealand. Barriers with the current equipment are the lack of equipment such asmultiple camera views, to target the specific performance objectives for feedback, equipment for information in more than one plane of movement and the ability for post training analysis.The investigation will use the current PA systems and design and adapt it to see whether it can be used in different ways and incorporate technical, tactical and physical aspects of Team Pursuit performance. Having a PA system and design that allows for more in depth analysis to be done, based on performance objectives, means that more of the potential 1% marginal gains in Team Pursuit can be addressed.

Phase Three: Design and Development.

The original systems and design of PA in Cycling New Zealand was used as the artefact and adapted to see if the equipment could be used to analyse the performance areas needed in the Team Pursuit discipline. The original design of video capturing was a side-on one camera view in the Velodrome, which focuesed on the sagittal plane movement of the athletes. The side-on view was located on the home straight of the Velodrome, as seen in Figure 3 below.

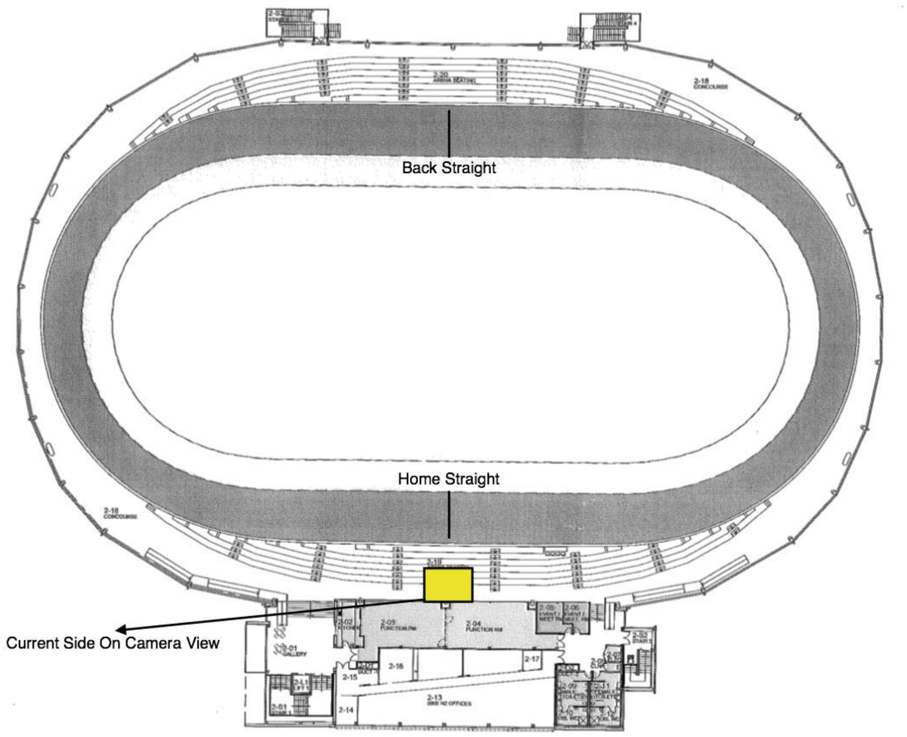


Figure 3. Current side-on capture view for filming training sessions. Design: Unkown.

Video was captured in training and shared through the software Sportscode™. Sportscode™ is a video analysis software that allows performances to be captured live through the use of a camera linked into the computer software. The video captured can then be analysed so feedback to be given back to athletes and coaches. Video is shared via Sportscode™ to athletes and coaches via a TV, located in the athlete pit area, so feedback can be given during a training session. As well as the capture of video done by the Performance Analyst, sports scientists capture physical data off the athletes' bikes on such measures as power, torque, cadence and speed fluctuations. After training sessions video is collated and stored on a video server (storage hard drive for all videos collected from training and competition) that is located at Cycling New Zealand, while the physical information is kept on an online platform.

Current Equipment description.

Sportscode™

Cycling New Zealand currently has five Sportscode™ licenses at all different levels of use. Two are elite licenses, one pro license and two review licenses. Below is a comparison of the different sportscode licenses and their capture abilities.

Table 2. Sportscode™ product comparisons between Pro Review, Pro, Elite Review and Review licenses, adapted from https://www.hudl.com/products/sportscode/tiers.

	Pro Review	Pro	Elite Review	Elite
Capture video live		✔		✔
Playback multiple angles	✔	✔	✔	✔
Capture multiple angles				✔
IP camera capture				✔
Instant multi angle review	✔	✔	✔	✔
Live copy of in game video on unlimited computers				✔
Smooth collaboration with Hudl replay				✔
Live Sportscode XML data during capture				✔

Sportscode™ Elite licenses are set up to currently capture the video at 50 frames per second and at a resolution of 720p.

Current Hardware

- Two sets of capture equipment, which includes:

  Blackmagic™ intensity extreme device (video capture device)
- Thunderbolt cable
- HDMI to HDMI mini cable – to connnect camera and capture device together
- Two Sony™ Camcorder Cameras (FDR-AX53 4k Handycam)

  The Sony™ Camcorders currently capture at a frame rate of 50 frames per second, HD resolution of 720p and a shutter speed of 1/600.

Using the current side-on view of training creates limitations in the type of analysis that can be done accurately and consistently. Many sports movements can be captured and analysed in one plane of movement with enough accuracy for analysis. Generally sagittal plane side views are common in running, cycling, gymnastics and other such sports (Pueo, 2016). This however, from a qualitative point of view, limits viewing movement that occurs in other planes, such as frontal plane of movement.

The current side-on camera view is not a fixed view. This means that analysing performance using tools such as overlay of footage or side by side comparisons cannot be accurately done, as the camera zooms in and out and pans to follow athlete movement. Having a camera fixed in the current side-on position would create visual problems on the far side of the track. The zoom needs to be applied to gather detail in the Team Pursuit, specifically aerodynamic positioning and line formation, key aspects of performance feedback. To be able to capture and analyse changes in a Team Pursuit effort more accurately, end-on footage could be used. A fixed view on either side of the velodrome (Figure 4 below) could allow for analysis tools such as overlay of footage, tracking of movements and accurate time stamps of where a change starts and finishes to be made.

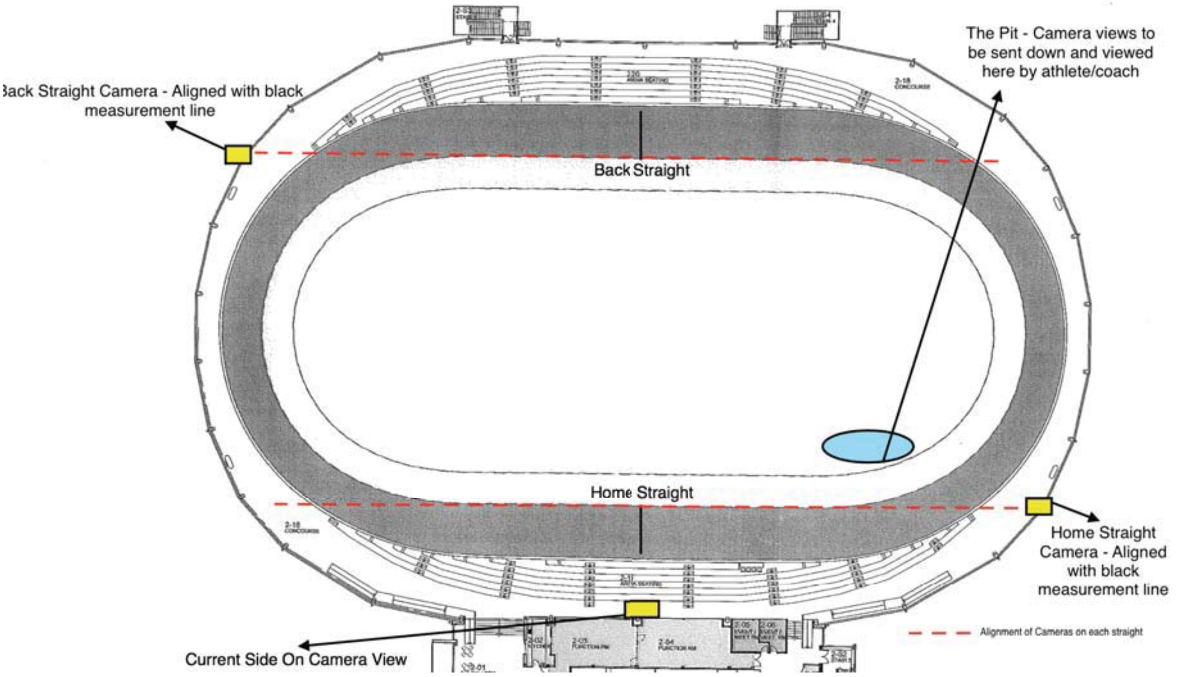


Figure 4. Velodrome image with the placements on potential end-on camera views. Design: Unkown.

Phase Four: Demonstration.

A trial was completed to investigate whether the current equipment in Cycling New Zealand PA could be used to add three camera angles to training for increased detail and feedback in the multidiscplinary areas of PA.

Having minimal PA equipment at Cycling New Zealand means only the current side-on view camera and one end-on camera could be used, eliminating the chance to capture video on one of the velodrome bankings, where changes in Team Pursuit occur. Team Pursuit changes occur on both ends of the Velodrome, as different riders stay in the front Team Pursuit position longer than others. Only having equipment to be able to capture one end of the Velodrome and the changes that occur there, will only capture half of the information needed.

Sony™ 4k Camcorders were set up on tripods, one side-on to the track and the other looking down the home straight of the velodrome. The cameras were connected to Mac computers via a blackmagic video capture device. The video capture device allowed the video to be captured in Sportscode™. The cameras were set to the current capture rate of 50 frames per second, resolution of 720p and a shutter speed of 600. Due to the restrictions on the types of Sportscode™ licenses that Cycling New Zealand has, both views could not be combined together and viewed at the same time for athlete feedback during the training session. This means that to review both camera angles, post session review would need to take place. Four training efforts of 3000m were captured of the mens endurance squad. This was done over a three hour training session.

The session was captured successfully and the two camera views were combined post training session using the “time stack” function in Sportscode™. This function allows multiple camera views to be merged together into one video file and creates a multi view video screen.

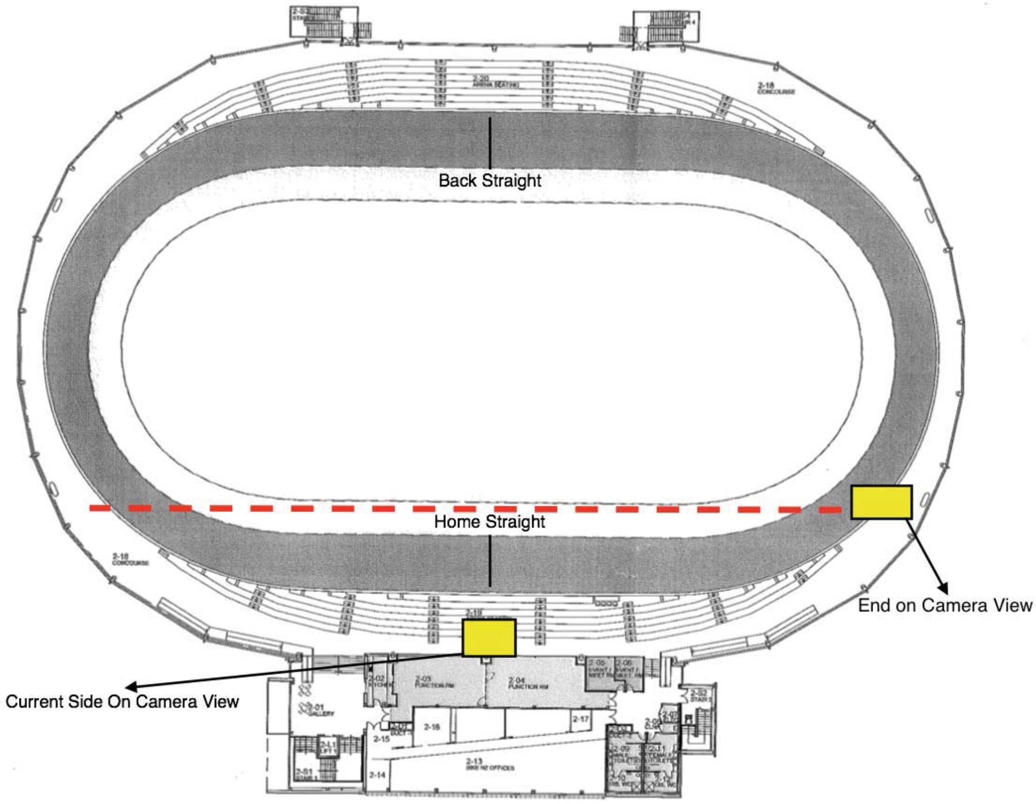


Figure 5. Velodrome design showing the positioning of the side-on camera and end-on camera. Design: Unkown.

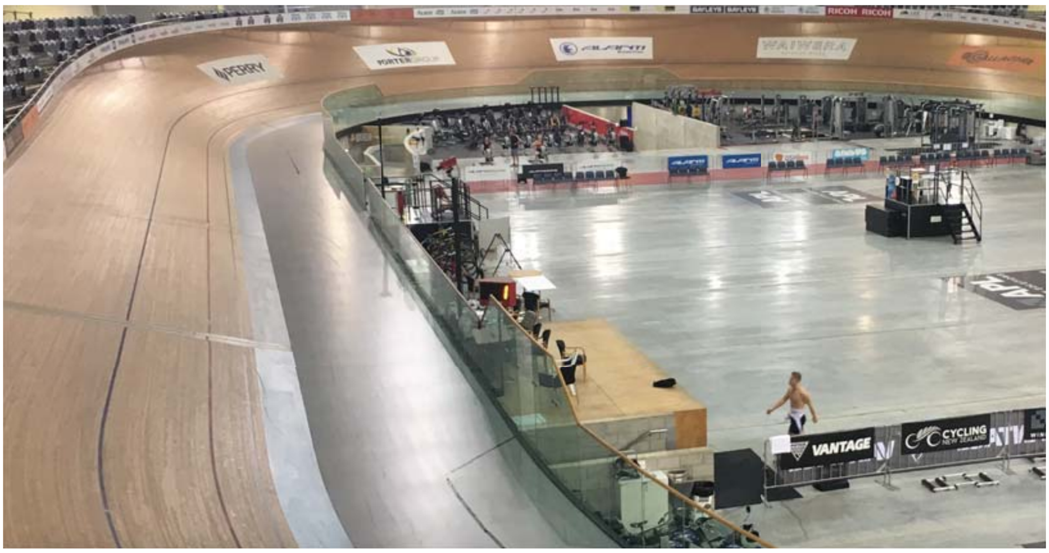


Figure 6. End-on camera view that is used to capture athletes team pursuit changes. Photo: Anna Higgins.

Phase Five: Evaluation.

Due to the unusual concept of having to review training post session, athletes never viewed the two views that were captured. The lack of an online platform where athletes could view the session from different locations was a problem observed.

Observational feedback.

The coaches found the multiple camera views incredibly helpful and from observation, found details in performance that one view would not have picked up. Specifically, line formation throughout a Team Pursuit effort and accuracy of changes were observed more in depth. Despite this, having to watch video captured post session was found to be more of an inconvenience. The inconvenience came from having to view training footage post session, rather than during the session. Post session analysis was an unfamiliar process to the coaches. The coaches were used to focussing on future sessions rather than the previous session that just occurred. The missing third camera view was also seen as a negative aspect as half of the athlete Team Pursuit changes were missed due to not having cameras on both straights of the velodrome. Changes occur on both ends of the velodrome, which means only having one end of the Velodrome captured by an end-on camera, the other end was missed in the video. Without the third camera view, comparisons, consistency in performance and overlay of all Team Pursuit changes for feedback was impossible to give accurately. Half of the athlete Team Puruit changes were not captured.

Equipment.

The equipment available to use at Cycling New Zealand, in the area of PA, created processing speed problems. Having to combine video views from the side-on and end-on cameras post session and then distribute to coaches was a process that was seen as being too slow and the video became more of an inconvenience to watch. Equipment upgrades need to be made to be able to speed up the feedback process.

Phase Six: Conclusion.

From the DSR investigation above on the current systems and design of PA in Cycling New Zealand, new equipment needs to be included and investigated to meet the performance areas identified by the Cycling New Zealand endurance coaches.

There were a number of conclusions drawn from round one of the DSR process:

1. Adding fixed camera views from multiple angles will allow for more in depth analysis to be done. Overlay and comparison of footage can be made with ease, as well as creating a further level of analysis from different

angles. Team Pursuit formation and lines can be viewed clearly from end-on cameras as well as the consistency of changes.

2. An Online platform to allow for easy viewing of training sessions and racing for athletes and coaches would improve the review and preview of a training session and analysis. This could also benefit post session review for athletes and coaches. Being able to view previous training sessions from away from the training setting would allow athletes and coaches to potentially buy-into analysing performance. Rather than focussing on a range of performance areas in training, analysis can be done post training focussing on further ways to improve performance. An online video platform would also allow for other elements of Track Cycling to be addressed, such as the tactical elements of racing in other endurance events to be analysing prior to competition.

3. Adding physical data and PA information together would help to develop a more detailed approach to performance for athletes and coaches. Power is a metric that is investigated in great detail for Track Cycling. Combining one of the key physical performance areas, such as power, with video and other PA information will help to bring a wider range of factors together to analyse performance.

Results:

Round Two of DSR Process

Phase One: Problem identification

From the previous DSR investigation above, using the current PA equipment of Cycling New Zealand, a need for further investigation into potential new equipment and PA systems design was identified.

From the previous investigation areas of improvement needed to be:

- Adding fixed camera views from multiple angles will allow for more in depth analysis to be done. Having camera views in multiple planes of movement such as sagittal and front planes, will create further areas of feedback for coaches.
- An online video platform would allow for viewing of training sessions and competitions for athletes and coaches. This will help improve the review and preview of training session video and analysis.
- Adding physical data and PA information together to develop a more detailed look on performance would help athletes and coaches.

A problem with the DSR process and moving forward into round two, is timing. The 2020 Olympic Games is two years away. The process of transferring to a new PA system and design needs to be simple and easy to accomplish in the time remaining. Creating too many changes in the athlete environment over the next year can lead to loss of buy-in to the PA system.

Phase Two: Objectives of Solution

The objective was to continue to investigate and improve the systems and design of PA in Cycling New Zealand. More specifically, to help build a multidisciplinary PA system to help with Team Pursuit performance and feedback for athletes and coaches. Moving forward, an investigation into software, hardware and analysis reporting will need to take place to make sure the right equipment is being used to provide the best possible feedback for coaches and athletes.

Phase Three: Design and Development

Multiple different areas of the PA systems and design needed to be investigated to make sure the objectives were achieved in this project. Hardware investigations such as cameras and the camera functions, capture devices, connection cables and computer types were investigated. Software for video capture and the type of software package that suited the needs of Team Pursuit, in Cycling New Zealand, was also investigated. The investigations continued further with the option of an online video platform. This would be used to combine well with the software and hardware selections made.

Hardware Investigation

Some of the key parameters to consider when choosing a camera for video capture include the frame rate and shutter speed (Corley, et al. (2015). Frame rate, also known as frames per second (FPS), can be defined as the number of individual frames that comprise each second of a video. In sports science and analysis, the speed of which a camera can sample moving images is a key feature for frame by frame analysis to be done.
To be able to calculate the frame rate the equation is:

Object velocity / Frame rate

For example, if a rider moves at 60km/h (16.7 m/s) and the frame rate is 50fps, the rider will move 33.4cm per frame. This is an accurate representation of speed for a team pursuit.
A frame rate of 50fps is currently used at Cycling New Zealand and is a high enough frame rate to capture information of the athletes, who can get up to speeds of 50 – 80km/h. The decision was made to keep the original frame rate of 50fps as the minimum specification moving forward.

"Motion blur" is the blurring or appearance of smudges surrounding an object that is moving at speed and its path of movement. The main factors that govern motion blur are the objects velocity and shutter speed (Pueo, 2016). Shutter speed is the amount of time that each individual frame is exposed for (Corley, et al. (2015). This is important in Track Cycling as it captures the athletes at speed without blurring of the footage occurring. The equation for working out motion blurring is:

Object velocity x shutter speed

For example, if a rider is travelling at 60km/h (16.7m/s) and a shutter speed of 1/600 is applied, there will be a blurring of 2.78cm (Pueo, 2016). When shutter speed is doubled, the exposure time for each frame is halved. The amount of light hitting the sensor is also halved. This means that the subject being captured needs high illumination if high shutter is used (Pueo, 2016). Due to Velodrome lighting only being used at full capacity for racing, lighting and illumination of riders in training can be a problem. Therefore, a shutter that is more than 1/600 tends to create very dark video to analyse. Having dark footage makes the analysis of fine details more difficult.

"Resolution" can be measured as overall size of a picture counting pixels. Typical video resolution is:

Pixel width x pixel height

High Definition (HD) resolution is currently used by Cycling New Zealand, at a resolution of 1280 x 720 pixels. This resolution is also used in the research of Faiss, et al. (2017), who looked at qualitative analysis in team pursuit Track Cycling.

Camera Investigation

IP (network) cameras are usually found in surveillance camera settings but have started to become part of analysing sports performance. IP cameras help in providing high quality footage and can be placed around sporting environments where the use of a tripod and camera to operate is hard to do. IP Cameras were seen as an ideal way to move forward with capturing footage for PA in Cycling New Zealand. The ability for the cameras to operate without an individual having to be there is key in an organisation with only one Performance Analyst. When a fixed camera view is all that is needed IP cameras also become very useful and a cost effective way of capturing performance.

IP cameras were selected based on whether they matched the specifications required (Table 2). The required specifications were found in the hardware investigation above. The IP cameras were also selected based on recommendations by other New Zealand sports and the ability to get the cameras in New Zealand. Axis™, Sony™ and Dahua™ were chosen as brands to investigate. A website search was done on each to find suitable IP cameras that met the specifications. Having technical support from the company that was providing the IP cameras was also an important aspect of this investigation. This was to allow the option for help if the cameras became problematic or had capability issues working with certain analytical software chosen. Due to the common use of Axis™ cameras and the easy availability of Dahua™ in New Zealand, these cameras were chosen to further investigate with a demonstration/trial in sections below.

Below is a table of camera specifications needed for Team Pursuit Track Cycling. Weight is added into the table, giving the option for permanent camera installation onto any of the beams surrounding the track. There was a requirement that the cameras would need to be under 4kg to be permanently placed in the Velodrome. The weight of the cameras is important due to the health and safety concerns when fixing cameras permanently above the track.

Table 3. Camera specifications for filming Track Cycling.

Minimum Camera Requirements						
Frame Rate	**Resolution**	**Shutter Speed**	**PTZ**	**Video Compression**	**Weight**	**Software Compatible**
50fps	720p	1/600	Yes	H.264	Below 4kg	Yes

Many sports movements can be captured and analysed in one plane of movement with enough accuracy for analysis. Generally sagittal plane side views are common in running, cycling, gymnastics and other such sports (Pueo, 2016). Plane of movement parallel to camera viewing position is not very common in science areas such as biomechanics. It can, however, be used to analyse a moving object in other planes of movement that a side-on sagittal plane cannot capture. The aim of the three camera views is to do this.

Three new camera angles were added to the Velodrome:

Adding three camera views to training: (Figure 7 below)

- Current side-on view
- Home straight view
- Back straight view

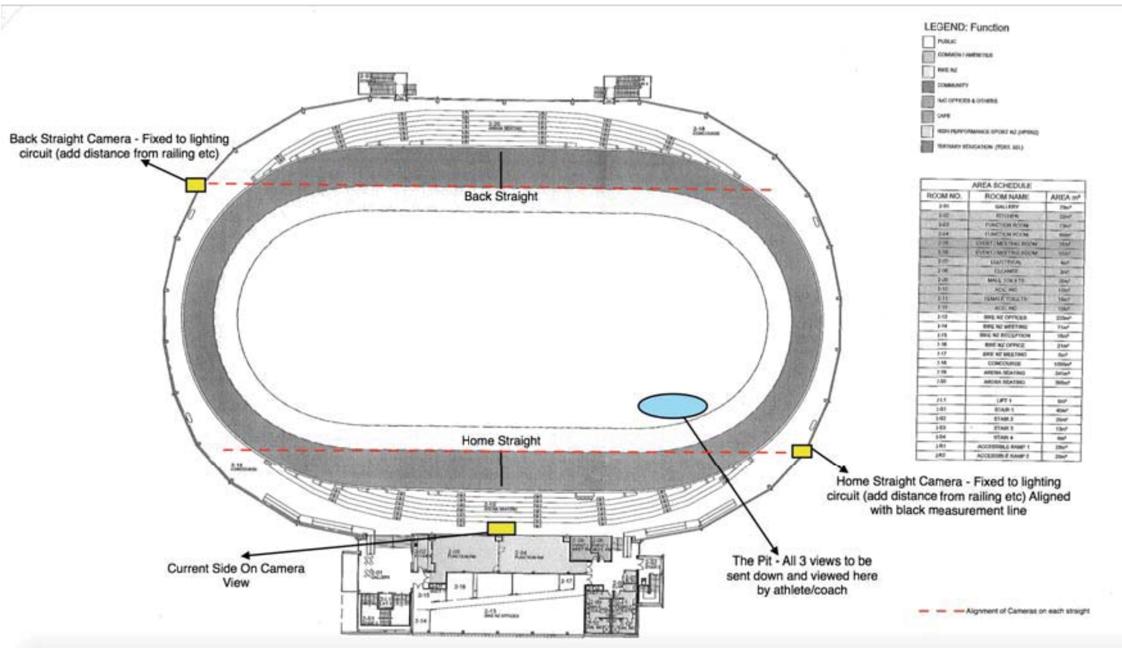


Figure 7. Showing the three possible camera points in the Velodrome, as well as their alignment with the home and back straights on the track. Design: Unknown.

Below are the camera views from each of the three new cameras in the Velodrome. The range captured in each view will include the opposite corner of the track, the straight of the track and pursuit line starts.

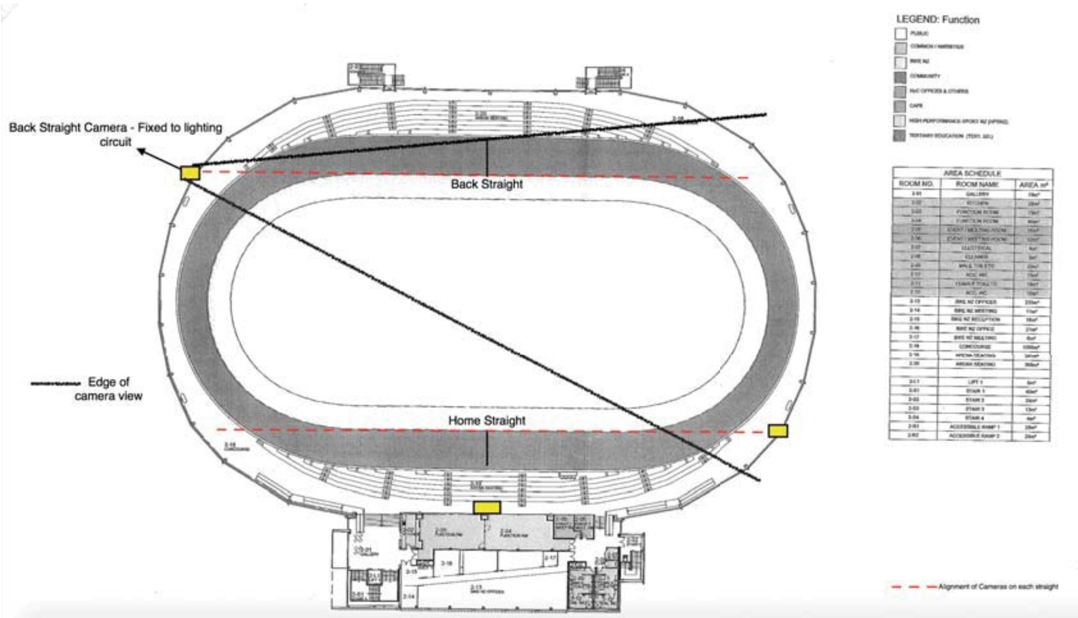


Figure 8. The back straight camera view in the Velodrome. This is indicated by the two black lines. Design: Unknown.

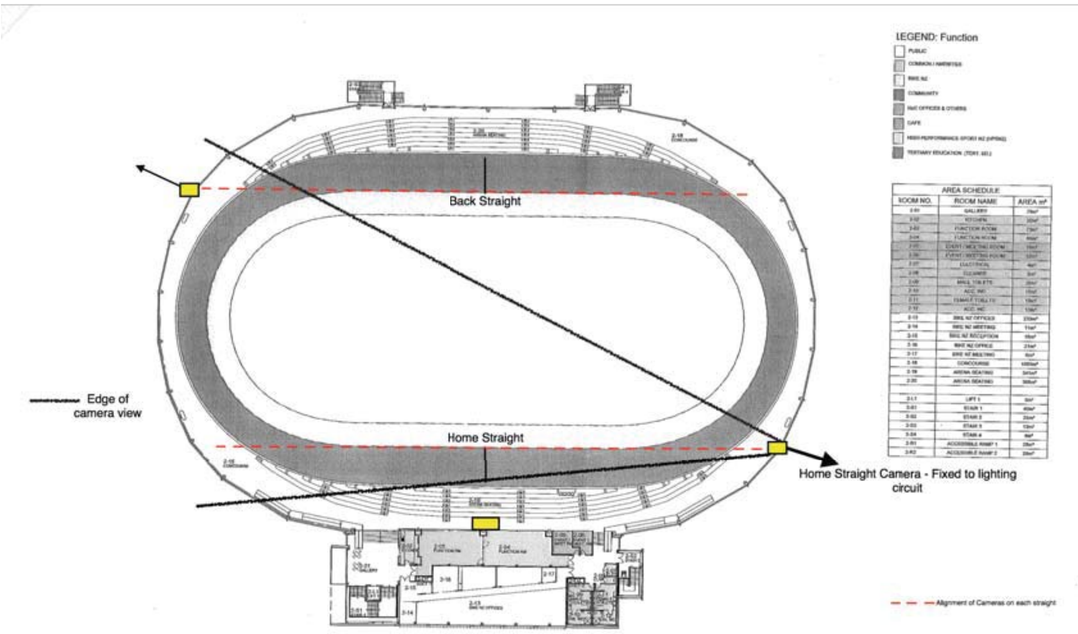


Figure 9. The home straight camera view in the Velodrome. This is indicated by the two black lines. Design: Unknown.

An investigation was done into the start and end points of a Team Pursuit change and where this occurs on the track. The height of a change was also investigated, shown in Figure 10 (below). This was to gather information on camera positioning and where the camera needed to be placed to capture the full change from the end-on view. From the images in Figure 10, using the advertisement signs on the track for guidance, the second sign on the track is where riders tended to exit the Team Pursuit change. The camera placement at the end-on point needed to be aligned at a wide enough position to capture from this point.

Figure 10. Three images showing the start, middle and end of the team pursuit change on the track, from left to right. Photo: Anna Higgins.

Once the width of camera view was decided from the above images in Figure 10, the next investigation was the establish how much of the Velodrome straight needed to be captured in the camera view. The first image below (Figure 11) allows for a direct view down the home straight of the Velodrome and allowed the focus to be purely on the Team Pursuit change. Having the second image, with more of the Velodrome home straight, allowed for detail in other aspects of Track Cycling, such as standing starts at the beginning of a race or training effort.

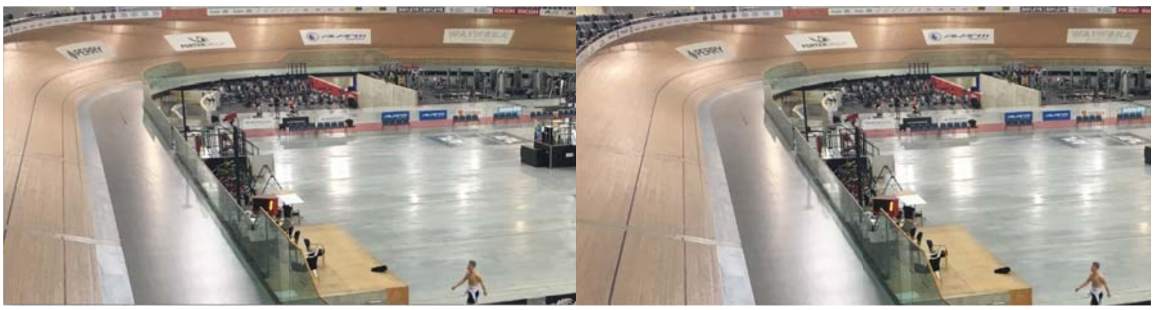


Figure 11. End-on camera views down the home straight to try and capture the full team pursuit change. Photo: Anna Higgins.

Software Investigation

Software was investigated to see whether there was a more suitable option for Cycling New Zealand, than the original option of Sportscode™. Sportscode™ was the original software package used for PA but there are a large number of other software options that could be considered for use in Track Cycling.

Software has become more readily available with technology advancing. Software such as Dartfish™, Sportscode™, Quintic™ and specific hardware devices have been developed in the area of PA (Bryant, James, Nicholls, & Wells, 2018). The software in Table 3 (below) was chosen to be investigated due to the use by other New Zealand sports and the recommendations made by others in the PA field in New Zealand. The recommendations came from Senior Performance Analysts in New Zealand sport who either currently using the recommended software or suggested software they thought would be appropriate for Cycling New Zealand. The software options were also chosen because of the ability to capture video live during a training session, which is the main task needed.

Table 4. Comparison of multiple different software options that could be a possibility for Cycling New Zealand.

Software Options	IP Camera Capability	Synchronised Views	Live Views	Post Analysis Views	Capture at Camera specs	Computer Interface	Time stamp for Sprinters	Output Analysis	Tagging Ability	Simulcam (frame movement)	Overlay of Video	Tracking Ability	Easy export of video files	Sprint Biomechanics	Bike fit/Aero mapping	Databasing of Video	Travel (use on the road)	Timeframe	Cost
Sportscode	✓	✓	4*	4*	✓	Mac	✓	✓	✓	✗	✓	✗	✓	Basic	Basic	✓	✓	6 weeks	$34,000
Dartfish	✓	✓	2 ?	4	✓	Windows	✓	?	✓	✓	✓	✓	✓	✓	✓	✗	✓	6 weeks	$1,765.32
Nacsport	✓	✓	1	4	✗	Windows	✗	Basic	✓	✗	✗	✗	✓	✗	✗	✓	✓	6 weeks	?$1,200
Angles	✓	✓	1	4	✓	Mac	✗	✗	✓	✗	✗	✗	✓	✗	✗	✗	✓	6 weeks	$6,000
Piston	✓	✓	15	15	?	iOS devices	? Can be added	✗	✓	✗	✗	✗	?	✗	✗	✗	✓	6 weeks	$10,000
Quintic	✓	✓	6	6	Provide cameras	Windows	✓	✗	✗	✗	✓	✓	✓	✓	✓	✗	✗	6 weeks	?
Goldmine	✓	✓	4 ?	4 ?	Yes ?	Windows	?		?	?	✓	✗	✓	✗	✗	✗	✗	??	
	Input						Analysis								Miscellaneous				Cost

From the comparison table in Figure 3 (above), further investigation was completed on the software packages, Sportscode™, Dartfish™ and Piston™. These three software packages met the highest number of requirements in Table 3 and were software packages that could be easily accessed through demonstration in a training situation at Cycling New Zealand.

Sportscode™

Sportscode™ provided a familiar platform for analysis at Cycling New Zealand. It was found to have a strong ability to use code windows (video information) and outputs (statistical information) to produce informative vidoe and data needed for PA. Cycling New Zealand currently had five Sportscode™ licenses, ranging from the Elite (top level license), down to review licenses. These are shown in the table below:

Table 5. Current Sportscode™ licenses that Cycling New Zealand had before the study occurred.

Current Type of License	No.	Cost (annually)
Elite License (top level)	2	$17,000 NZD
Elite Review	1	$4250 NZD
Pro Review	2	$4200 NZD
	Total:	**$22,950** NZD **(discount for 5+ licenses)**

To be able to use Sportscode™ for the project (three camera views), change needed to happen to the type of licenses used by Cycling New Zealand. Below is a table of packages were needed:

Table 6. Sportscode™ licenses that could be used by Cycling New Zealand with three camera views.

Type of License	No.	Cost (annually)
Elite License (top level)	3	$25,500
Elite Review	1	$2250
	Total:	**$27,500 (discount would apply)**

Benefits of Sportscode™

Below are the benefits and limitations of Sportscode™ from a Track Cycling perspective.

- Provides "time stamp" (Figure 12) for sprint cyclists to get precise timings of splits during training and racing. This is used on a daily basis and is a key part of having sportscode.

Figure 12. Time stamp tool in Sportscode™ used for time splits.

- Sportscode™ was familiar to riders and coaches. It is the current system being used in Cycling New Zealand (before this study was conducted).
- It was found to be able to bring three camera views in "Live" for prompt review by riders and coaches. **To do this requires different licenses then we currently have.*
- Sportscode™ brought capture footage in at the specification levels needed for high speed Track Cycling (50-80km/h).
- It functioned off iOS/ Mac. Cycling New Zealand currently has all the computers needed to run Sportscode™ software.
- Found to have the ability to create video databases with optimal information (Figure 13).

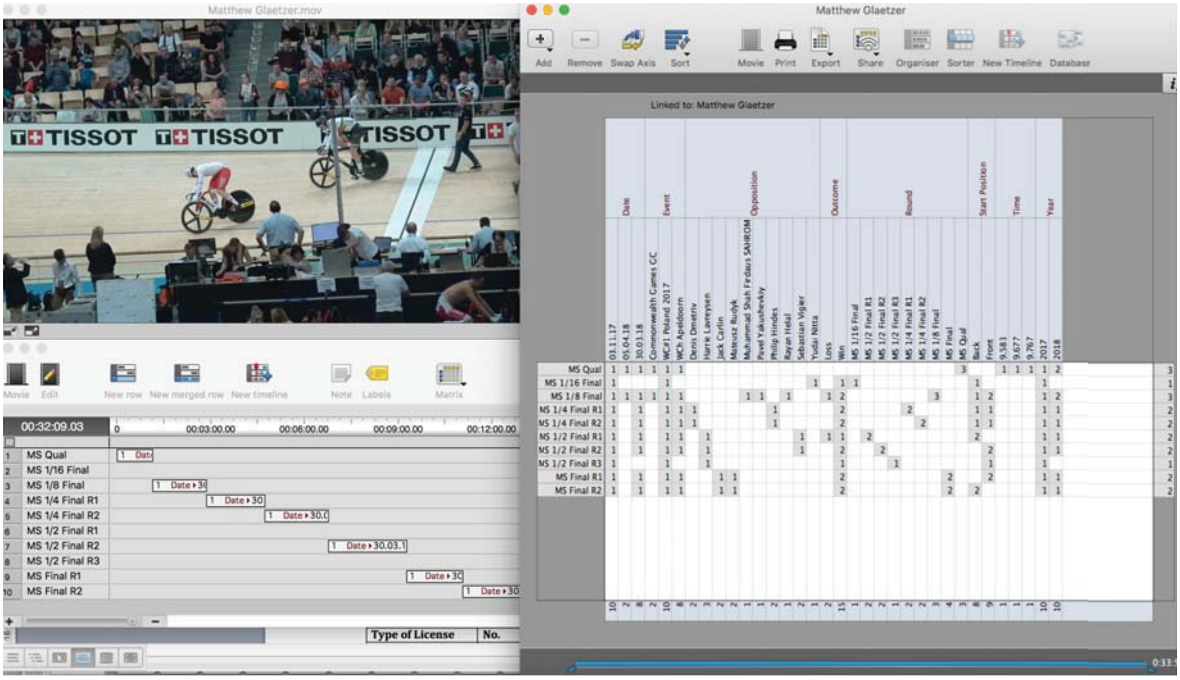
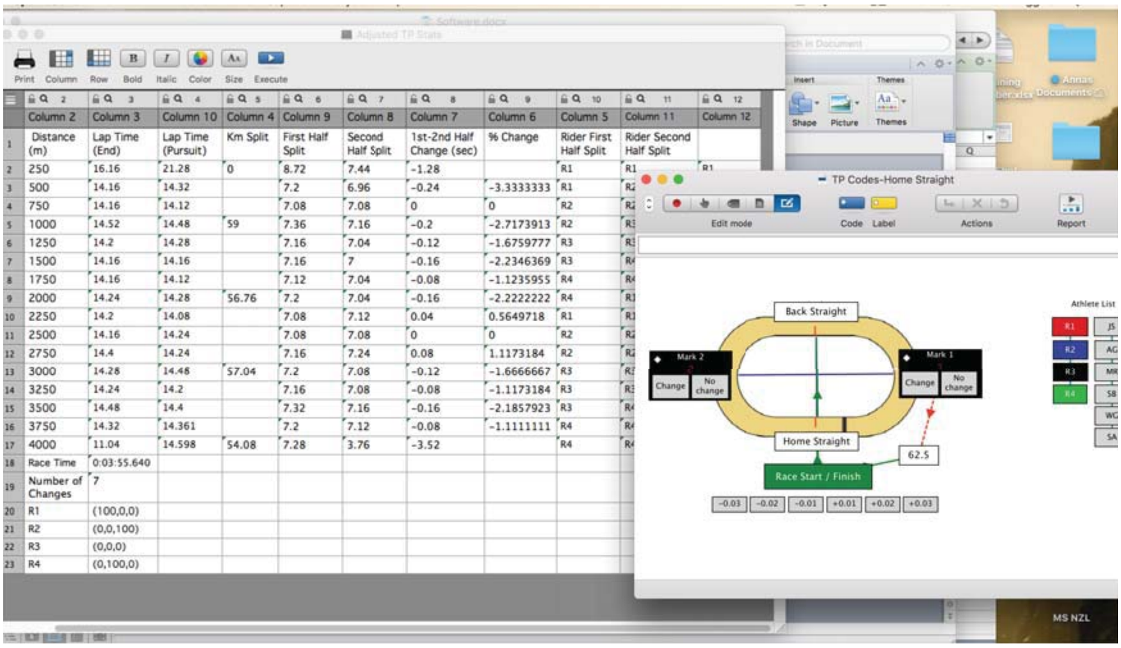


Figure 13. Matrix analytical tool in Sportscode™, used to display statistical numbers using video.

- Sportscode™ had easy export options for data and video during racing and training while abroad at major competitions. This was done by viewing information on IPads. (Chosen PA method of viewing video while travelling for training and racing).
- Had the ability to easily create output windows for gathering of key training and racing data. This was used for Team Pursuit analysis of opposition teams during key competitions (Figure 14).



Distance (m)	Lap Time (End)	Lap Time (Pursuit)	Km Split	First Half Split	Second Half Split	1st-2nd Half Change (sec)	% Change	Rider First Half Split	Rider Second Half Split
250	16.16	21.28	0	8.72	7.44	-1.28		R1	R1
500	14.16	14.32		7.2	6.96	-0.24	-3.3333333	R1	[illegible]
750	14.16	14.12		7.08	7.08	0	0	R2	[illegible]
1000	14.52	14.48	59	7.36	7.16	-0.2	-2.7173913	R2	[illegible]
1250	14.2	14.28		7.16	7.04	-0.12	-1.6759777	R3	[illegible]
1500	14.16	14.16		7.16	7	-0.16	-2.2346369	R3	[illegible]
1750	14.16	14.12		7.12	7.04	-0.08	-1.1235955	R4	[illegible]
2000	14.24	14.28	56.76	7.2	7.04	-0.16	-2.2222222	R4	[illegible]
2250	14.2	14.08		7.08	7.12	0.04	0.5649718	R1	[illegible]
2500	14.16	14.24		7.08	7.08	0	0	R2	[illegible]
2750	14.4	14.24		7.16	7.24	0.08	1.1173184	R2	[illegible]
3000	14.28	14.48	57.04	7.2	7.08	-0.12	-1.6666667	R3	[illegible]
3250	14.24	14.2		7.16	7.08	-0.08	-1.1173184	R3	[illegible]
3500	14.48	14.4		7.32	7.16	-0.16	-2.1857923	R3	[illegible]
3750	14.32	14.361		7.2	7.12	-0.08	-1.1111111	R4	[illegible]
4000	11.04	14.598	54.08	7.28	3.76	-3.52		R4	[illegible]
Race Time	0:03:55.640								
Number of Changes	7								
R1	(100,0,0)								
R2	(0,0,100)								
R3	(0,0,0)								
R4	(0,100,0)								

Figure 14. Statistical window and code window in Sportscode™, used to analysis Team Pursuit performance.

- Sportscode™ was found to be able to use IP cameras as well as standard video cameras to capture video.
- Tagging of footage during live capture or post analysis was found to be possible, creating key video clips out of racing and training.
- Had the analysis tools with the ability to overlay footage and move frame by frame through video for more in depth analysis.
- Had an online platform option that is directly linked into Sportscode™ for easy video export.

Limitations of Sportscode™

- Cost – The cost of Sportscode™ compared with other software almost doubled in price.
- A Sportscode™ license was required at each camera be used, which means three different computer/monitoring sources were needed to capture all three camera angles.
- Due to cost restrictions in the area of PA, and Cycling New Zealand funding options for PA being restricted, Sportscode™ was hard to justify on a cost basis.

Dartfish ™

Dartfish™ software had the ability to analyse performance with multiple tools, such as overlay of footage and frame by frame movements. Dartfish Pro was a software that offered multiple “Live” camera angles to be captured and up to four camera views that were placed together post training session for analysis and feedback. Dartfish™ was the current software used by bike fit in Cycling New Zealand. bike fit is the area of support covered by Physiotherapy in Cycling New Zealand. The role of bike fit is to provide the athletes with the best possible positioning on the bikes for areas such as seat height, length of bike, handle bar positioning, crank length, hip range and how much power can be produced in certain positions. The outcome of this is to establish the best aerodynamic positioning possible for each athlete. Providing a Cycling New Zealand license for multi user purposes, meant that it could of been utilised to analyse track performances and for bike fit needs.

Table 7. License and cost of one Dartfish™ software purchase.

Type of License	Number Needed	Cost (annually)
Dartfish Pro S	1	$ 1765.32

Benefits of Dartfish™

Listed below are the benefits and limitations of found of using Dartfish™ as a software package for Cycling New Zealand.

- Up to 4 views were able to be combined for post training and PA (Figure 15).

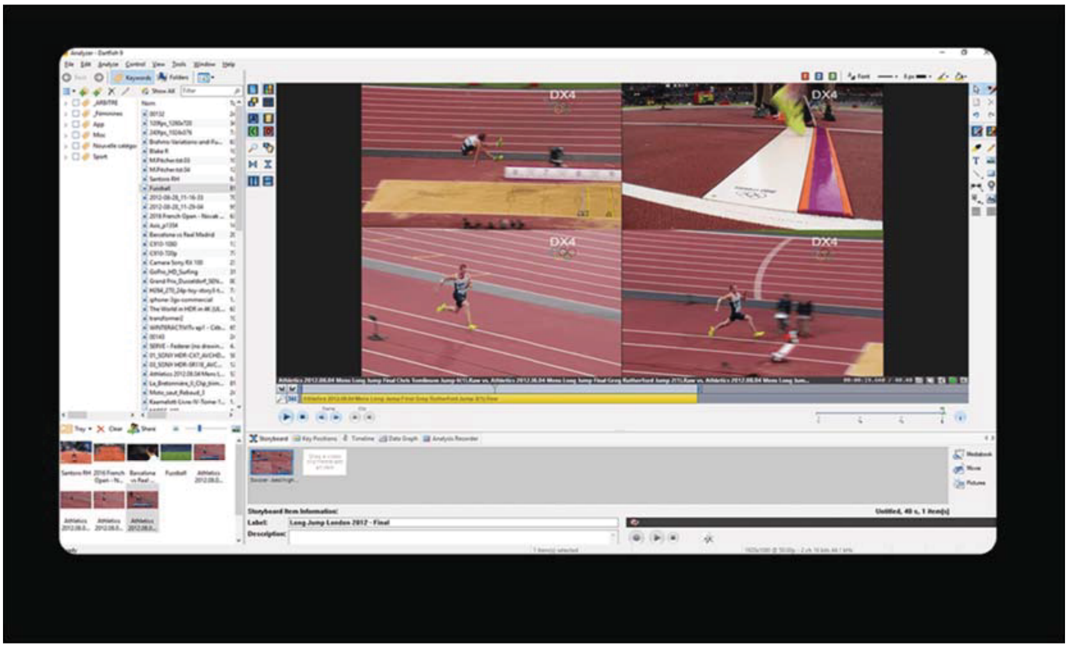


Figure 15. Dartfish™ four camera view video option. Retrieved from: https://www.dartfish.com/pro.

- Dartfish™ captured video at the rate of camera input, which meant capturing occurred at the required specifications needed.
- It was found to use “stromotion and simulcam” to analyse performance. If chosen as the software package, options for overlay of video, as well as frame by frame athlete movement (Figure 16).

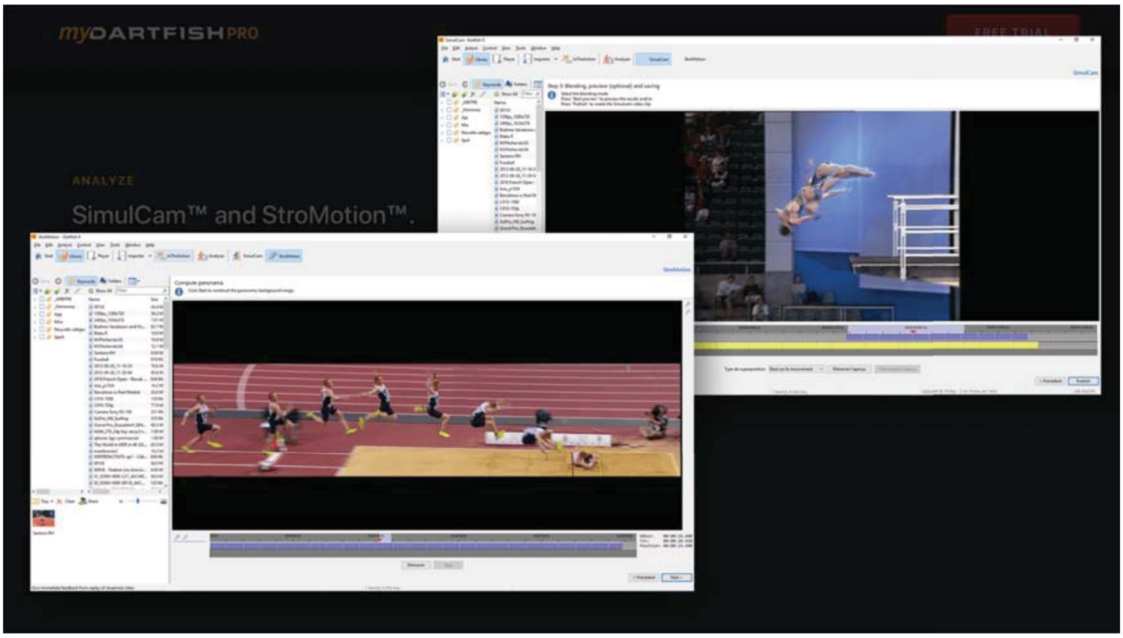


Figure 16. Dartfish™ analytical tools used to analysis frame by frame movement and overlay of athlete video. Retrieved from: https://www.dartfish.com/pro.

- Dartfish™ allowed “bike fit” staff to analyse bike positioning and movement with ease. Overlay of movements and continuing the use of tools such as biomechanical angles on the video, to improve aerodynamic positioning would be of great benefit to the riders.
- Ability to import mp4 files would in future allow for seamless transition with Cycling New Zealand’s current footage, which has been exported to mp4 files for viewing by athletes and coaches.
- Dartfish™ was found to use IP cameras as video input as well as standard video cameras.
- Dartfish™ tagging footage capabilities during live capture or post analysis, would allow for specific clips to be made of performance.
- Offered “timestamp” capabilities needed to be able to create time splits at different points in a training effort or race.

Limitations of Dartfish™

- Dartfish™ was found to have the ability to only capture two views “live” which meant all three camera angles (side-on and two end-on views) of the athletes would not be possible.
- Output features for Team Pursuit analysis were not as advanced as Sportscode™ software that Cycling New Zealand currently has. A new way to analyse opposition Team Pursuit performances would need to be created.
- Dartfish™ operated from Windows™ computer systems only. PA at Cycling New Zealand would need to either run parallel Mac™ and Windows™ options from the current iOS/Mac computers or new laptops would be needed to operate Dartfish™.

Angles™

Anlges™ software is a capture and editing tool for PA. It allowed multiple IP cameras to be viewed at once, as well as the ability to “pinch and zoom” video for a more in depth look at footage. Pinch and zoom is the ability to use 4k camera footage and zoom in on the video after capturing, to maximise information that can be seen.

Table 8. License and cost of Angles software.

Type of License	Number Needed	Cost (annually)
Angles	1	$6,000 approx.

Benefits of Angles™

The benefits and limitations of Angles™ software seen from a Track Cycling perspective are discussed below.

- *Angles*™ was found to view multiple camera angles for post training session and competition analysis.

Figure 17. Multiple camera view video option with Angles™ software.

- It provided the opportunity for "pinch and zoom" feature which can allow footage to be viewed at a closer view point.
- Was found to tag/"mark up" footage during live capture or post analysis, which allowed specific clips from a performance to be captured.
- Angles™ was found to have a vault video platform for storing files which could create ease when accessing videos that have been previously captured. The vault video platform would act as a video storage system.
- Angles™ had the ability to import Sportscode™ timelines and mp4 files (previous videos and Sportscode™ xmls. that have been used).
- The capability was found to add in "time stamp" clock for sprinters to take splits from (this is a future project for Angles™ staff).
- Angles™ could also add data graphs to a timeline (timeline seen in the bottom half of Figure 17), to display external sources of data with the video. This would benefit Cycling New Zealand by combining physical data that is collected off the athlete bikes to be added alongside the video.
- Angles™ was built to work alongside the Piston app/software investigated below.

Limitations of Angles™

- Cannot capture three views “live” for viewing during a training session.
- Did not offer analysis capabilities such as overlay of video or analysing tools to help with displaying areas of improvement to the athletes.
- Angles™ would not offer time stamp capabilities needed for the sprint cyclists to take timing splits during training.
- Angles™ is a new product to the market. Issues may arise that are unknown throughout the first few months of use. It is an unfamiliar product to use for the athletes and coaches, so time for education and learning would need to take place.

Piston™

Piston™ is a server system that allows video and xml files to be sent to IPads/IOS devices for viewing during a training session. IP cameras are used to connect into the “Piston™ Server Box” which acts as a server.

Figure 18. Piston™ Server box that is used to connect all IP cameras.

The Server box consists of IP camera connections and signals to be able to produce multiple camera angles to be displayed on an iPad. Piston would be used with an external data source (such as Sportscode™, Dartfish™ or Angles™) mentioned above to allow post session analysis to be done on the video captured.

Table 9. Cost of a Piston™ application license and the server box.

Type of License	No.	Cost (annually)
Piston	1	$10,000 approx
(above cost is license and server box installation combined)		

Benefits of Piston™

Discussed below are the benefits and limitations of Piston™ software package from a Track Cycling perspective.

- Was found to have the ability to stream up to 15 angles lives to iPads/iOS devices.

Figure 19. Example of the Piston™ iOS IPad software application.

- Easy to use by swiping left or right on the iPad to switch between different camera views

- Easy to connect, with the ability to start a capture and select cameras needed for the session in one simple action directly from the IPad. This would give the coaches the ability to use cameras if the PA is absent.
- Tagging live from an iPad, creating specific video clips in performance.
- Pinch and zoom abilities.
- Allowed for "live" import of xml data (which appears on the side in Figure 19 above).

Limitations of Piston™

- Piston™ was only viewed on iPad or iOS devices. This means Apple™ TV would need to be purchased to link the iPad into the TV for coaches and athletes to have accesss to footage on a larger screen during a training session (additional cost of approximately: $249.00 NZD).
- Did not offer "time stamp" capability that the sprint cyclists use to take time splits during training.
- Piston™ is designed by a new company and product (debugging problems could occur).

Phase Four: Demonstration

The Demonstration phase of the DSR process involved trialling the potential systems that could be utilised at Cycling New Zealand. Both hardware and software were trialled to find the best possible system and design. The demonstration phase allowed the coaches to use a new product and give feedback on its effectiveness.

Dahua™ IP Camera

The Dahua™ 2MP Broadcast PTZ IP Camera was tested by a High Performance New Zealand Performance Analyst that had access to a trial camera. This was done in the South Island of New Zealand, where the Dahua™ camera providers are located. The trial made sure that the specifications such as minimum 50fps, high shutter and 720p quality resolution were available. Footage of the trial was captured and sent through to view. The IP camera allowed for all the right specifications to be met. The online platform controlled the pan, tilt and zoom feature to allow for movement of camera before a training session. A trial was done to see if a HD resolution of 1080p could be used, but this showed little change in footage quality between the 1080p and the 720p. From the trial conducted, the Dahua™ IP camera met the minimum specifications needed for the new system and design at Cycling New Zealand.

Piston™ and IP Cameras

A Piston server and system was sent to be trialled at the Velodrome, along with an IP camera (Axis™ P1448-LE Network Camera). The IP camera did not meet the frame rate specifications needed but had a shutter speed and resolution of high quality. Two training sessions were used to trial the Piston™ system. The sessions were a mixture of sprint and endurance cycling and lasted three hours in length.

The Piston™ system operated off iPads that Cycling New Zealand had already purchased for overseas travel use. The IP camera was set up on the track with an end-on view of the home straight in the Velodrome. Cycling New Zealand has a number of iPads used for training and competing abroad (eg. World Championships and World Cups). An iPad was set up with the Piston™ application to be able to trial the product. The session captured was a mixture of sprint and men's endurance training. Both were more physical based sessions but were still helpful to gather whether the system was easy to operate and displayed what was needed for feedback.

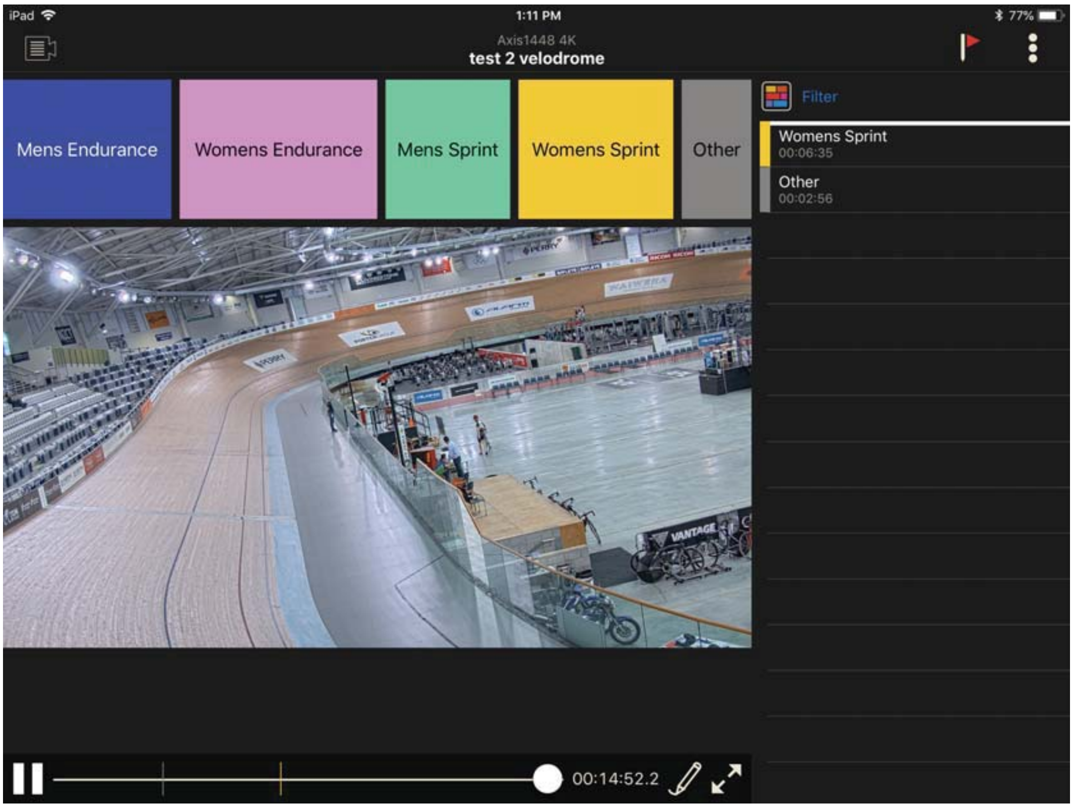


Figure 20. IP Camera view captured during the Piston™ trial session. Photo: Anna Higgins.

The Team Pursuit coaches were asked for feedback verbally on the effectiveness of the Piston™ system. The feedback given was that the system was "easy to use" and could be a "game changer" for the men as squad. The detail that could be seen with the extra camera views, allowed the men's squad to add more depth into analysing the techniques and performances overall.

From a Performance Analyst perspective, the system had a number of features that worked well. It was very easy to use, the iPad was very portable so analysis and feedback could be viewed from anywhere (trackside, in the stands, in the athlete pit). The camera views were crisp and to change between different views was easy to use. Alongside the positive aspects of the Piston™ system, there were a number of challenges. Having a side-on camera that requires a zoom function, such as the current Sony™ 4k Camcorder, created an issue due to the Piston™ server only set up for IP camera inputs. To get around this issue a Blackmagic™ video capture device (H.264) was used to feed the Sony™ Camcorder into the Piston server as well. This function allows for any type of camera to be used with this system.

Dartfish™

Dartfish™ is a software option that is operated off Windows™ computer system. The transfer from Sportscode™ (Cycling New Zealand's current system) to the Dartfish™ system is not straightforward. Due to the 2020 Olympic Games being only two years away, and the fast approaching Olympic qualifying season, the transfer of files and the change in systems and design to Dartfish™ was a major project. It was decided that Dartfish™ would not be our main software used for the next two years but definitely would be considered post Tokyo 2020 Olympic Games and beyond.

Despite Dartfish™ not being the main system for Cycling New Zealand, Dartfish™ offered analysis tools that could be of great benefit for Team Pursuit.

Sportscode™

Sportscode™ is the current software used at Cycling New Zealand,. Already having access to Sportscode™ licenses made testing easier than the other software options. Due to being only able to test with two cameras (Cycling New Zealand's current cameras), only two views were combined for a training session to test the effectiveness of Sportscode™ in this way. The first view was the current side-on sagittal plan view, using the Sony™ 4k Camcorder. The second view was also a Sony™ 4k Camcorder at the end-on position of the home straight in the Velodrome. A Sony™ 4k Camcorder, Mac laptop (with an Elite Sportscode™ license), and a Blackmagic™ capture device, were set up at each camera site. The captured views were then combined through the use of the Sportscode™ function of stacking footage together. Both views were presented on the TV in the athlete pit. The view on the TV was very familiar to both coaches and athletes. This meant that navigating the two views was done very easily. From a Performance Analyst perspective, the two camera view arrangement was easy to manage but would be more technical with three views and the cost of products and equipment for three views would go up significantly when using Sportscode™. The next step in the demonstration phase of the DSR model was to find a way for Sportscode to have three camera views all being presented at once, during a training session.

Three view cameras: IP cameras with Sportscode™

Due to the complex nature of finding a way to incorporate both IP cameras and a Sony™ Camcorder into the same capture device, one of Sportscode's regional representatives offered assistance in the process of trialling and finding the right products for this. IP cameras were investigated and sourced within New Zealand so that easy communication and support could be given if required. These cameras also work alongside Sportscode™ in New Zealand which made the process more seamless. Dahua™ IP cameras were also chosen based on their ability to work at the same frame rate, shutter and resolution of the Sony™ Camcorder and the minimum specifications required in this project. To minimise cost of Sportscode™ and to limit the amount of computers and Sportscode™ licenses that would be needed to be purchased, an investigation and demonstration occurred of how decoders could work to capture what is needed.

The problem of having an HDMI output from the Sony™ Camcorder and then two IP Camera feeds meant a connection needed to be found that would take both HDMI and IP into the same feed and then be able to display this in Sportscode™. A video server and a decoder were found with the Dahua™ IP camera company (Dahua™ Channel Smart 4k&H.265 Lite Network Video Recorder and Truen™ TS – 30000 video server). The video server was found to be able to send the Sony™ Camcorder footage to a decoder and pair it with the two IP feeds. These could then be displayed in Sportscode™ using the same Blackmagic™ video capture device that Cycling New Zealand currently uses. Figure 19 (below) shows the connections that occurred.

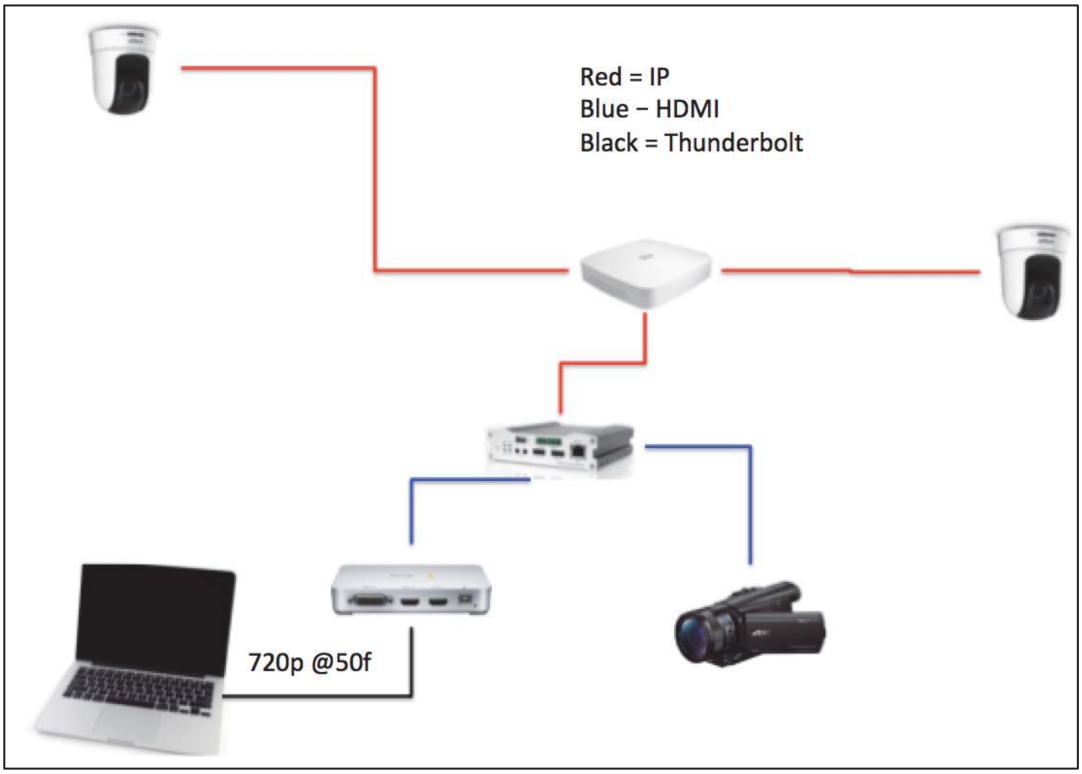


Figure 21. The connection system and hardware needed for the three camera view video system with Sportscode™ software. Diagram: Anna Higgins.

The three-view IP camera and Sportscode™ system was then trialled with the Team Pursuit in training to gather feedback from coaches and observational feedback as a Performance Analyst. The session consisted of four Team Pursuit efforts lasting for approximately three minutes each. The three views captured were sent down to the TV for the athletes and coach to view during efforts and were later uploaded to the trialled online platform (Hudl™) to view post session (discussed later in the demonstration phase of the DSR process). The photo, Figure 20 (below), shows the three views combined and how they appeared on the TV in the athlete pit.

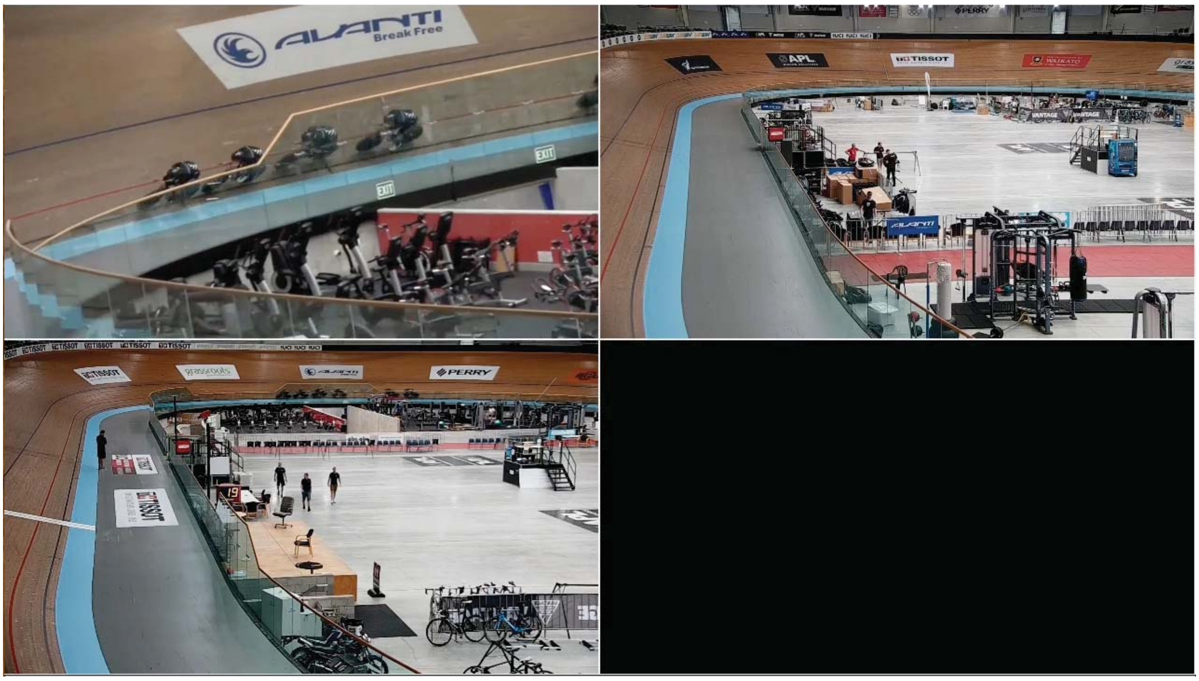


Figure 22. Three camera views using the Dahua™ IP Cameras and the Sony™ Camcorder. Photo: Anna Higgins.

During the trial of the Sportscode three views, the exploration of ways to improve feedback to coaches and athletes on performance objectives was demonstrated. From the new fixed IP cameras, tracking of changes was trialled and presented to the coaches as feedback. The free application Kinovea™ was used as cost effective way for this to happen. Kinovea™ is a free downloadable program that gives the PA the ability to analyse performance with tools such as movement tracking. Figure 21 below shows the end image product of one of the riders changes that was used as a trial. Each change in a training session effort was tracked for every rider involved to see if there was consistency across the team and individually.

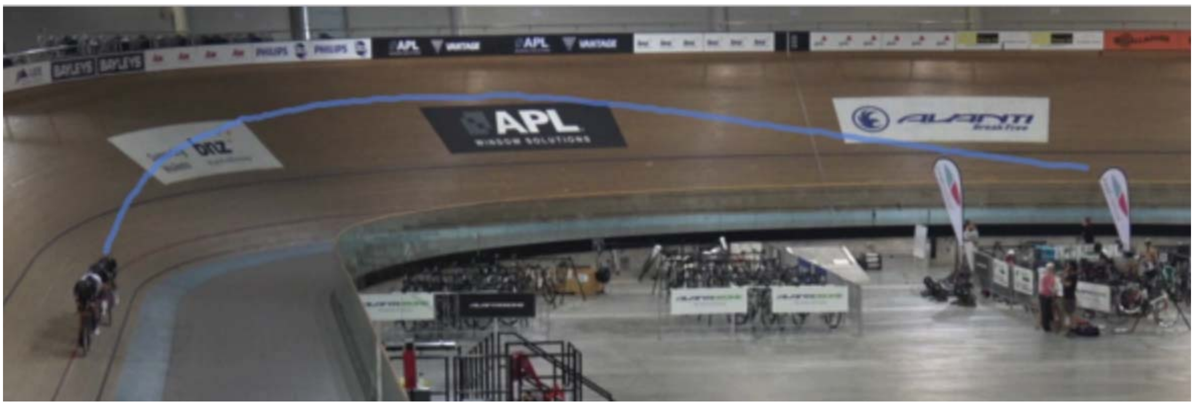


Figure 23. Tracking of Team Pursuit change using the new fixed camera views and Kinovea™ software. Photo: Anna Higgins.

Introduction of a Video Online Platform

Currently, Cycling New Zealand does not have a system where athletes can access videos post training or competition with ease. Having an online platform that athletes and staff can access video on from anywhere with internet, would be beneficial for Team Pursuit and other disciplines that Cycling New Zealand focuses on. In a study by Bryant, James, Nicholls, & Wells (2018) it was found that most Olympic and Paralympic elite coaches liked video to be provided post performance and during a performance. Using the online platform would allow during and post session video viewing to happen.

Hudl™ is a company who also designs the software Sportscode™. The online platform was seen as an easy to use video viewing platform that can be accessed online via phone and iPad/Tablet. Hudl™ also links in well with Sportscode™, having a direct upload from the Sportscode™ software to the platform.

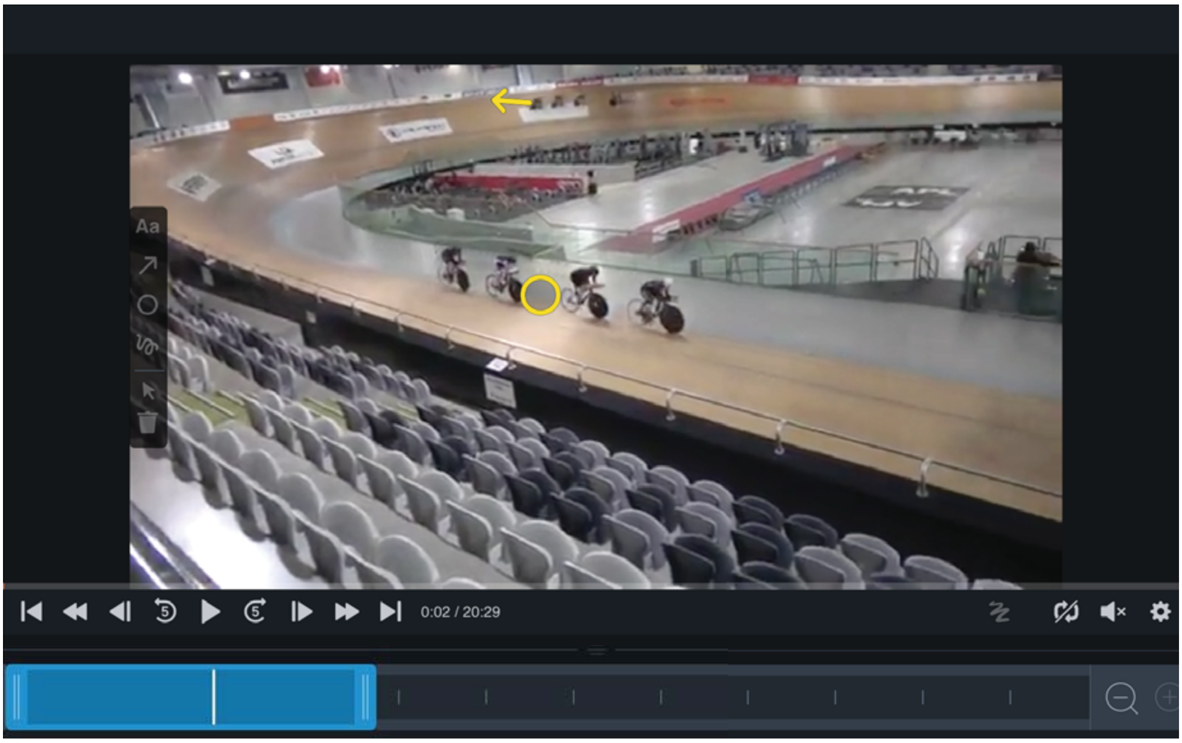


Figure 24. On video drawings done using the Hudl™ online platform. Screenshot from: Cycling New Zealand Hudl™.

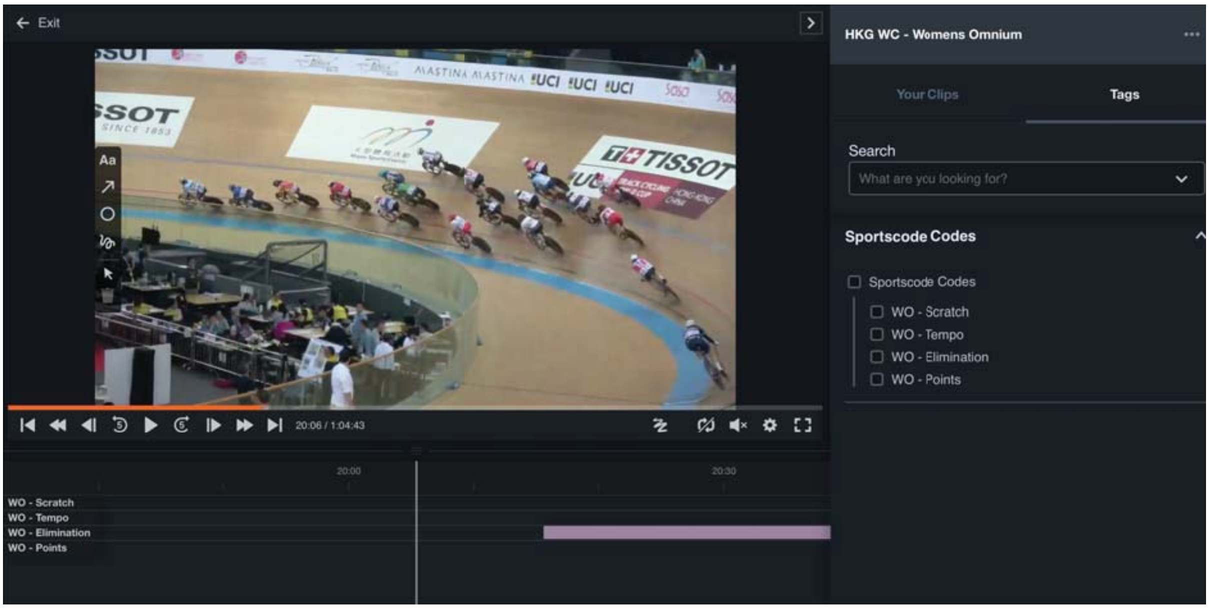


Figure 25. Showing what the Hudl™ online platform looks like for athletes and coaches. Screenshot from: Cycling New Zealand Hudl™.

Hudl™ was chosen based on the feedback given from other sporting teams in New Zealand. It is also well streamlined with Sportscode™ and other analytical software that can produce video and xml files. It was trialled with training footage of the women’s endurance squad to see if the features for commenting, drawing and providing feedback were easy to use, from a PA perspective. The online platform needed to be simple for athletes and coaches to access and use without assistance from PA. Hudl™ was presented to the endurance coaches with full explanations on the way it could be used to benefit Cycling New Zealand. The online platform was displayed on a TV, to the coaches , with uploading of a video, clipping and drawing key information onto a video and writing comments on the videos shown to the coaches. From there it was decided by the coaches when the introduction of Hudl™ would take place with the athletes. Hudl™ was introduced to one of the endurance teams as a trial to see how the team interacted and used the online platform. A presentation was given, similar to that of the coaches presentation, and the athletes were shown how to use Hudl™. This presentation took place just before a training session, with that training later being uploaded as the first video for the athletes and coaches to view.

Athlete and coach usage was tracked during the first few weeks of athletes and coaches using Hudl™. The use of Hudl by the women’s endurance athletes changed based on the training session uploaded. Usage of Hudl™ by the athletes was tracked using the “manage team’ option in Hudl™. This displays the time in which each athlete or coach spends watching video on Hudl™.

Phase Five: Evaluation

The evaluation phase of the DSR model looked at the demonstrations that were conducted above and evaluated each one. Feedback was gathered from participant observation, reflective notes and informal interviews with coaches. The evaluation phase helped to determine future direction with the DSR process using PA.

Observational Summary: Software

The Sportscode™ option of software has many positives and achieves the objective of creating multi-view video capture. It is a familiar software for both coaches and athletes that helps provide the feedback needed on performance objectives.

The demonstration using the decoder and video server to gather three camera views in Sportscode™ worked well and achieved the objectives. The minimum specifications were met and both in session and post session analysis could be done.

Three Camera Views

- Showed discipline in the Team Pursuit line and how accurate the riders are at being able to staying directly behind the front rider.
- Gave the opportunity for footage to be used with analytical tools such as overlay and frame by frame movement. Having a fixed camera made this possible and allowed more information to be drawn from video captured (Figure 23).
- Gave the endurance cycling coaches more effective feedback tools to report back on performance objectives.
- Men's endurance found some "gems" in the video but all three views can be confusing to view all at once. One example of the "gems" found was the line formation of the Team Pursuit out of the Velodrome bankings not being as accurate as once thought from the side-on original camera view.
- Need to focus on one view and make others secondary for more information (limits confusion that can occur from looking at three views at once).
- Can add physical data into this visual information to give more of a multidisciplinary approach to feedback

Hudl™ Online Platform

An online platform for video has not been used in Cycling New Zealand to date. Adding this into the systems and design of PA, allowed post session review to be done from anywhere with the Hudl™ platform being online. Hudl™ is also an application that can be downloaded to a phone or iPad/Tablet. The participation observation data showed athletes were engaging in the platform. The coaches buy-in helped by getting the athletes to watch footage post training session rather than mid-training. Coaches gave athletes analysis homework to do from the videos uploaded, from more of a tactical point of view. "Homework" would consist of athletes looking at aerodynamic positioning during an effort, from a technical point of view. From a tactical point of view, bunch racing strategies of opposition riders were analysed and the athletes were asked to provide their thoughts on tactics those riders attempted or succeeded at performing. For the platform to remain effective and continue to be used to analyse performance, there needs to be consistency with uploading footage. Tactical footage also needs to continue to be uploaded to help athletes engage in analysing performance and learning.

Feedback from Coaches

The feedback gathered from the endurance coaches on the effectiveness of Hudl™ was positive. Hudl™ empowered the athletes to look at technique and added the opportunity for them to perfect the Team Pursuit further. Athletes were able to focus in on all aspects of technique post session, rather than during the training session, where more specifics are targetted with technique. The athletes could use more time away from training to look the technique and where improvements needed to be made. This is a new concept for Track Cycling in New Zealand so having buy-in for post session review is a big step forward in the use of PA to help feedback. For racing it brought the ability to repeatedly watch and gather more information on individual and team performances. Hudl™ gave the ability for the whole squad to collectively view video or assess performance individually. Separating into individual endurance Track Cycling disciplines such as Omnium and Madison allowed for technical and tactical elements of racing to be analysed and trends with opposition to be further investigated. A suggestion by one of the coaches regarding Hudl™ was to look at tracking athletes over the season and using tools more effectively in Hudl™. Another suggestion was having individual videos gathered on Hudl™ for each athlete to show season progression.

Three-view camera system

The coaches in this study found that the three camera views helped with feedback by providing more visual information on the performance objectives from different angles, but could be confusing to look at all three camera views at once. The coaches and athletes found some “gems” of information from the three cameras as the views provided more information on looking at aerodynamic positioning as well as lines on the track. A negative aspect of the three view approach was it took more energy and buy-in to watch all 3 camera views at once. Moving from the original video view of one side-on angle, to then having three views on the TV adds a lot more detail for athletes and coaches to grow familiar with. There is a need to learn how to look at one view and use the others as secondary information. Time is a big factor in elite sport and cycling and the coaches found they have not used all three camera views enough to get used to feedback given with them. Due to the different types of training sessions completed, at certain phases of preparation for competition, and with major Olympic qualification events approaching, timing to trial the new products was limited.

Moving forward

Feedback from coaches suggested the following improvements could be made in future:

- Following distances and power numbers of athletes to be integrated into the video and analysis
- Quantifying mistakes from athletes

The coaches found that these improvements would help to integrate the physical aspect of performance with the technical and tactical information from the video analysis.

Another potential area to move forward with was adding a Go Pro™ to the bikes to get a “Rider” perspective of lines taken on the track/following distance and efficiency.

Tracking changes, as shown to coaches (Figure 23), is an aspect of PA, fed back from coaches, as an area that needs to continue. This can be done in technique focused phases of training. Collecting a baseline of an individual’s Team Pursuit changes and tracking consistency and accuracy. Tracking changes in Kinovea™ started a conversation with coaches and other support areas of staff to address performance questions on what is the optimal change and whether its individualised or all should be the same across a team. A collaboration of physical aspects of a change and combining these with the visual footage will help to start build a potential model of what the best possible change is in a Team Pursuit.

Limitations of the Demonstration Process

A main limitation was the cost/trade off of benefits and weaknesses between consumer and industry products in PA (Giblin, et al. 2016). The gold standard industry (shown in Figure 26) has products that would be highly suitable to use in Cycling, but due to cost constraints and funding, the PA systems and design needed to be investigated, through this project, to see what is possible with software and hardware on a budget.

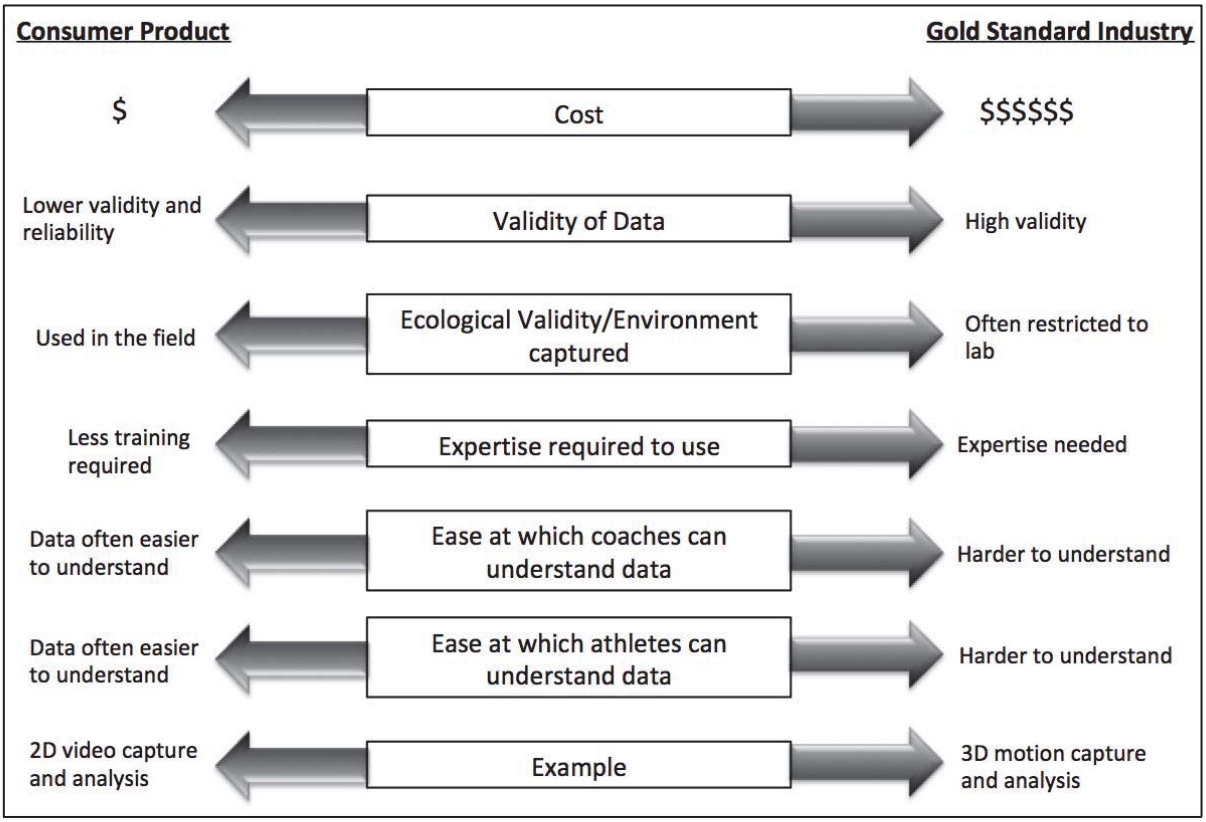


Figure 26. Adapted from the Giblin, et al. (2016) model of cost/trade off benefits and weaknesses between consumer and industry products.

Due to cost restrictions the gold standard or the best possible systems and design were not possible at Cycling New Zealand. Having to look into ways of still getting the most suitable software but reducing cost was a hard task. The introduction of the video server and decoder to bring multiple views into Sportscode™ without the cost of extra computers and Sportscode™ licenses helped to achieve the outcomes set in collaboration with the coaches at the start of the project.

Another limitation that was present with the DSR process in this project was timing. Due to the Tokyo Olympic Games being less that two years away and a key qualification season starting a few months post information collection in the project, major changes could not be introduced as time was going to be a limiting factor. Staying with Sportscode™ is the main software avoided a lot of timing issues that would of occurred. It is also very familiar to athletes and coaches which meant buy-in through learning a new software was not an issue.

Multidisciplinary Approach

The next stage of the DSR model would be to integrate more multidisciplinary areas such as physical metrics. The systems and design is in place to be able to produce PA information to support feedback on performance objectives and pair this with physical data. More time is needed to establish how this can be reported effectively and efficiently. The physical metrics and the technical aspects of performance are now aligned and what is being looked at can now move toward being combined into multidisciplinary feedback.

Phase Six: Communication

The last phase of the DSR process is the communication of findings with relevant stakeholders. The results of the design process were communicated to the coaches and relevant staff on the changes that were made in the PA systems and design. From the feedback that was gathered in round two of the DSR process, ways of improving the new changes were suggested by coaches. Due to the up-and-coming Olympic qualification events for Cycling New Zealand time was limited to trial products and them apply the products to help with feedback before the season started. These suggestions will be investigated further and will be part of future directions.

Future Recommendations

Below are areas of recommendation that could be added to the PA systems design process in the future:

1. Tracking of athletes changes to overlay footage, add timing and power numbers and show consistency in Team Pursuit performance.
   - From the tracking of changes, feedback could be presented on consistency of the full Team Pursuit group or individuals within the group.
   - Power and time physical data could be added to the visual aspect of the Team Pursuit changes to give a larger overview of what occurs for each athletes to be able to gain consistency.
   - Start to develop an idea of what an "ideal change" looks like in Team Pursuit through modelling.
2. Add Go Pro™ footage for a rider perspective in a Team Pursuit effort.
3. Continue communication with coaches to be able to keep performance objectives known and at the front of PA systems and design.

Technical Report Discussion

The primary aim of this project was to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. To achieve this, a design science methodology was used to implement changes to the current systems at Cycling New Zealand based off recommendations in the investigation of video and PA systems. The findings were presented to relevant staff in Cycling New Zealand as a technical report (see chapter 3). The key findings from this project will be discussed in this section, drawing on key literature in areas such as marginal gains in cycling, multidisciplinary PA, feedback, software and hardware and the DSR process. The discussion will consider practical recommendations, future research directions and the strengths and limitations of the project.

This research is the first study to apply DSR in the elite sport context. The exploration of the DSR concept in elite sport opens a new pathway for implementing changes in systems and design into applied areas in sport. While analysis systems and design have been evaluated in the sporting context (Carling, Collins, & Wright 2014; Corley, et al. 2015), the implementation of recommendations made in these studies has been limited. Having a framework such as the DSR model creates an easy to use pathway for sports practitioners to align performance objectives and coach driven performance questions, with systems and design of PA.

The research project aimed to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. It also aimed to:

1. Investigate current PA systems and video use and evaluate the systems against PA literature.
2. Use a DSR method to implement changes to the current systems and design at Cycling New Zealand based off recommendations in the investigation of video and PA systems.
3. Communicate changes and ways to improve to relevant staff.

The focus of this project was founded on coaching feedback and developing PA to be able to help the feedback process on performance objectives more effectively. Making sure, during the study, that performance objectives remained the same and were communicated, as well as allowing the coach to give feedback on the changes and improvements in PA, helped to retain a strong relationship between coach and analyst. Coach philosophy plays a big role in performance objectives and the areas of interest to a coach. Bryant et al. (2018) found that 90% of PA's indicated that coach philosophy or experience impacted on the analysis and direction of analysis that was done. It was suggested that the ability for Performance Analyst's to communicate coaching philosophies into variables and behaviours that can be analysed, is an important aspect of the PA process.

Following on from this, it was found that an effective coach-analyst relationship where both parties can contribute views and knowledge was the best guide to PA provision (Bryant et al. 2018).

The study aimed to adopt a multidisciplinary approach to PA within New Zealand Track Cycling. However, this was only partially met during the research conducted. The aim of addressing all areas of the technical, tactical, physical and psychological aspects of the Team Pursuit and bringing the information together was not completed. Technical and tactical elements were introduced well. This can be seen in the positive feedback from the coaches. However, physical areas of analysis were not aligned, nor were the psychological area of sports science. In Cycling New Zealand, there is support in all aspects of performance, with experts working in all areas of sports science. Collaborating and combining information is a current limitation in the Cycling New Zealand organisation. Small pockets of collaboration occur but if collaboration of information was to improve this could benefit performance in Cycling New Zealand. The findings of this study suggest that PA and video are areas of sport science support that can be a focal point for sport science collaboration. The collaboration of PA, coaches, sports scientists and other areas of support providing data, can be instrumental in the development of informed practice (Bartlett, & Hughes, 2002).

In this study, the researcher-analyst encountered some challenges in engaging coaches in discussions around PA and video, such as changes in coaching personnel, limited time in the schedule to interview coaches, and limited direction provided by some coaches regarding their needs for PA. The research aligned with the findings of Bryant, et al. (2018), that found there was a lack of information regarding the value of PA and feedback from a coaching perspective. Making sure the coaches were providing feedback and the area of PA understood performance objectives was very important. Like any area of analysis, it is clear that the effectiveness of PA is affected by coach buy-in to PA (Reade, Rodgers, & Hall, 2008). Following the meeting when the findings of the study were fed back to the coaches, greater buy-in was observed in PA support by the coaches, and subsequently the athletes. It could be argued that with multiple sport scientists competing for coaches' attention, buy-in to PA, and any area of sport science, will be influenced by coaches' perceptions and the importance they place on each area. PA is a relatively new area of sport science support (Mackensie & Cushion, 2013), and is establishing itself within high performance environments. Alongside the coaches, the buy-in of athletes is also an important area for consideration in PA. Athletes and staff in high performance culture are confident in their abilities and can be sceptical about the value of new approaches or different regimes (Eubank, 2014). Poor athlete buy-in can be problematic and by understanding the perspectives of the end user with PA/feedback, evidence based strategies can be used to improve user buy-in and engagement

(Cotterill, Jobson, & Neupert. 2019). The buy-in of athletes was explored in this project with the introduction of a new online video platform. The Hudl ™ online video platform was introduced to allow athletes (and coaches) the opportunity for pre/post training and competition analysis of technique, as well as tactical analysis in other endurance events in Track Cycling. Buy-in was again the key to integrating PA into the environment (Reade, Rodgers, & Hall, 2008). The process of introducing the new PA system was approached by allowing the coaches to use and see value in the online platform, before introducing it into the athletes training and competition environments. After the coaches saw value in the platform it became part of the training analysis and feedback process for them, as well as the athletes. Coaches asked the athletes to complete homework and allowed them to watch the video of training from home rather than track side during a training session. This was positively received by the athletes and engagement was high. Compared to the low levels of engagement in PA observed at the start of the study, this marked a real change in approach by the coaches.

The advances in software and hardware technology have allowed sports scientists and PA to measure key aspects of performance that previously have been confined to a laboratory setting. Given the large array of tools available in the area of technology and sport and the desire for more in-depth information to be collected rapidly, coaches and applied scientists need to be careful in selecting the appropriate technology tools needed (Giblin et al. 2008). During this research, it was important to stay focused on the aims and objectives of the study when looking into technology changes. The outcomes of this project at Cycling New Zealand aligned with the findings from Corley, et al. (2015), who supported the use of video as a tool which allows coaches to review, reflect and evaluate the development of athlete preparation for a major race, both qualitatively and quantitatively. The introduction of three camera views and an online video platform made review, reflection and evaluation even more significant to the coaches and provided them with the tools to analyse athlete performance in depth. Combining several video camera views and video from the front, side and back views, coaches can have several different perspectives of an athletes performance that wouldn't be seen by normal observation (Wilson, 2008). The online platform made viewing footage and information more accessible. The new system also allowed for feedback to be given rapidly in a training session, or the video could be edited, processed and reviewed for post session feedback online (Corley, et al. 2015).

Strengths and Limitations of the study

Buy-in through the introduction of a new PA system, the online video platform was a significant strength to the research. Post training video reviews of performance did not happen previous to the introduction of the online video platform at Cycling New Zealand. Video-based PA would be analysed during a training session, in between training reps, which limits feedback discussions and the focus of the session. Having an online platform where athletes and coaches can go to view training and competition footage, analyse performance and review video has been a well-used addition to PA at Cycling New Zealand.

Another strength of the research was the DSR model and process adapted from Bragge, et al. (2006). The model created a clear guide of how to investigate PA in cycling. The DSR process is a new approach to use in sport but is well suited to building and/or creating new systems and design. Having a new framework, such as the DSR model, to implement changes in PA and other support areas, is a good addition into research in elite sport.

A further strength in the research was applying PA to coach performance objectives. It is an important part of investigating and changing systems and design in PA. Performance objectives set by the coaches are what drives feedback to the athletes. Making sure these align with the PA that is being done allows more accurate and beneficial feedback to be given in the coaching process.

One of the main limitations in the research was the time available to conduct research and trial products in the Cycling New Zealand environment. Due to the fast approaching first Olmypic qualifying events and the need for athletes to focus in on execution of performances, rather than technical information in depth, there was a small opportunity to trial and demonstrate new products during training and gather feedback from coaches. More time was needed to fully explore each potential software package and hardware camera option before making a decision on which pathway to take.

Having a small feedback group was another limitation in the research. Athletes are one of the key users of PA and video-based feedback. Having greater feedback from the athletes would allow more buy-in to the PA process and help to change or improve more aspects of the PA systems and design to suit the feedback process, based on the performance objectives. The coaches feedback was instrumental in the future direction that this DSR project will have. Allowing athletes the chance to add to this feedback would grow more depth into the decision making process.

Practical Recommendations

- Continual use of the DSR model to investigate and implement changes in areas of PA and other support within the elite sporting context.
- Continue to work toward a multidisciplinary approach to PA and areas of support. Allowing a strong collaborative environment to benefit all areas of performance.

- Strong communication between practitioners and coaches to allow for understanding of key performance objectives in the sport. Making sure all areas of support are aware of the aims and objectives of the specific sport so the expertise can be applied appropriately.
- Athlete perspectives to be captured on the introduction of new products and systems in the performance setting. The athletes are one of the main users of performance systems. Gathering feedback from athletes on improvements that can be made could be highly beneficial in making sure alignment between performance systems and the sporting objectives is occurring.

Conclusion

The aim of this thesis was to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. PA is an important part of the coaching feedback process. It provides objective data to inform and support the coaching process and is an integral tool within the coaching (Byrant, et al. 2018). In a high performance environment, that relies on good performances for funding, high levels of pressure and stress to perform well are very common (Gould, Gruinan, Greenleaf, & Chung, 2002). Having a PA system and design that create ease with feedback and helps coaches and athletes toward marginal gains in performance can be instrumental. In this project within Cycling New Zealand, investigating the use of video and PA systems in the Track Cycling environment, aligning PA systems and design with coach led performance objectives, was a step toward helping with marginal gains. The exploration of a new model, such as the DSR model, has created great opportunity in the future for other researchers in elite sport to ultilise this approach. The introduction of multiple camera views and an online video platform were changes made to the PA process at Cycling New Zealand with buy-in from coaches and athletes, as well as behaviour change had to occur to make these changes possible. Through a strong Performance Analyst and coach relationship, communication and good feedback allowed for changes to occur and future directions to be found through the project. The investigation into PA in Cycling New Zealand and the effectiveness of the systems and design, has set the process in motion of collaboration between different areas of sports science. The multidisciplinary approach to PA (Glazier, 2010) and continuing to combine technical, tactical, physical and psychological areas of sports science together for PA has begun with this project and will help to guide future direction in PA at Cycling New Zealand.

Chapter Four: Thesis Discussion

The primary aim of this project was to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. To achieve this, a design science methodology was used to implement changes to the current systems at Cycling New Zealand based off recommendations in the investigation of video and PA systems. The findings were presented to relevant staff in Cycling New Zealand as a technical report (see chapter 3). The key findings from this project will be discussed in this section, drawing on key literature in areas such as marginal gains in cycling, multidisciplinary PA, feedback, software and hardware and the DSR process. The discussion will consider practical recommendations, future research directions and the strengths and limitations of the project.

This research is the first study to apply DSR in the elite sport context. DSR can be usually found in design, technology and information research studies. The exploration of the DSR concept in elite sport opens a new pathway for implementing changes in systems and design into applied areas in sport. While analysis systems and design have been evaluated in the sporting context (Carling, Collins, & Wright 2014; Corley, et al. 2015), the implementation of recommendations made in these studies has been limited. Having a framework such as the DSR model creates an easy to use pathway for sports practitioners to align performance objectives and coach driven performance questions, with systems and design of PA.

Summary of Results

Round One. The first round of the DSR process examined the current systems and design of PA in Cycling New Zealand, to evaluate if performance objectives were being met and whether changes needed to be made to align more closely with the performance objectives of the Team Pursuit discipline. The investigation showed, through observation, the need for changes and improvements to be made with the systems and design of PA in Cycling New Zealand. There were multiple areas of the original system and design that could be improved to benefit PA. Having one camera view restricted the plane of movement that could be seen by coaches and athletes during feedback. The other limitation was having no post training session review platform or a way coaches and athletes could review footage and analyse. The further detail from multiple camera views and fixed camera options could help the PA system and design to align with the performance objectives in more detail, especially the efficiency of the Team Pursuit changes. The online video platform would allow for analysis and feedback to be done after a training session, rather than having pressure on feedback during a training session. Software and hardware options for PA needed further investigation. The current system at Cycling New Zealand covered the basics of PA but did not benefit the feedback process of coaches with the alignment to performance objectives.

Round Two. The second round of the DSR process was more in depth than round one. It required an investigation into changes and improvements that needed to occur in software and hardware, within the training environment. This was undertaken in order to meet the needs of the Team Pursuit performance objectives outlined by the Olympic Track Cycling coaches. Round two explored ways to incorporate a multidisciplinary approach to analysis through combining technical, tactical and physical areas of analysis. From the investigation it was found that:

- Sportscode™ was the most flexible software and able to work to meet the needs of Cycling New Zealand.
- Dahua™ IP Cameras were added to the hardware portfolio. A three camera view was incorporated into the training for more detail to be shown in feedback.
- Hudl™ Online Platform was introduced as a pre and post training session and video/feedback tool, which allows coaches and athletes to review training sessions online from any location, on a laptop, phone or iPad//tablet, taking away the limitations of feedback confined to during a training session.
- The combination of all of the changes above allowed for two out of the identified three areas of a multidisciplinary approach to occur. Technical and tactical elements were combined through the use of an online video platform for pre competition analysis and post training and competition analysis.
- Physical elements of analysis will be incorporated in future investigations and changes in PA at Cycling New Zealand.

The research project aimed to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. It also aimed to:

4. Investigate current PA systems and video use and evaluate the systems against PA literature.
5. Use a Design Science method to implement changes to the current systems and design at Cycling New Zealand based off recommendations in the investigation of video and PA systems.
6. Communicate changes and ways to improve to relevant staff.

From the aims and objectives above, the research addressed these points well. An investigation into Cycling New Zealands PA systems and design was completed and evaluated using the multidisciplinary model of PA by Glazier (2010). A DSR method was used to further investigate and make changes to PA where necessary. The changes and improvements made were based off coach performance objectives set at the start of the research. These performance objectives centred around the Team Pursuit discipline and focussed on aerodynamic positioning, Team Pursuit line and formation, technique under fatigue and change-overs that occur between athletes mid-race. The research was communicated to the coaches and relevant staff and feedback was gathered on any changes or improvements made to the systems and design of PA.

In the remainder of this discussion section, the key findings from this project will be discussed in relation to key literature, including marginal gains in cycling, multidisciplinary PA, feedback, software and hardware and the DSR process.

Marginal Gains

Marginal gains can be defined as an accumulation of a number of small gains that there becomes a result in a larger gain in overall performance and have been used as a strategy in opposition cycling teams such as Great Britain (Hall, James, & Marsden, 2012). In Olympic sport, the line between winning and losing is becoming thinner (Birrer & Morgan, 2010). Due to short funding cycles between World Championships and Olympic Games (1-2 years), the need for marginal gains in a short amount of time is crucial. The PA changes made in this study were made to help toward the gathering of 1% marginal gains in all areas of performance. PA and the multidisciplinary areas of technical, tactical, physical and psychological analysis were seen as areas, through performance objectives, that could help toward marginal gains. The results and feedback from coaches on the positive affects the new PA system and design had on areas such as line formation in the Team Pursuit, will be beneficial moving forward toward the Olympic Games, where marginal gains are crucial in winning performances. British cycling performance director, Dave Brailsford, stated that breaking down everything that could contribute to riding a bike, and improving it by 1%, would show a significant increase in performance (Hall, James, & Marsden, 2012). This concept was adopted by British Cycling for the 2012 and 2016 Olympic Games, giving them multiple gold medal performances.

These small changes in all support areas of performance could lead to significant differences in cycling performance in New Zealand. The application of DSR as a methodology for identifying marginal gains is a concept that can be applied to other areas of support, including Physio, Strength and Conditioning, Psychology, Nutrition and Sports Science. Like PA, these support areas are focused on identifying and improving aspects of competition performance which can increase the number of medals won and medallists developed (Bryant, et al. 2018). Like other sport scientists, the Performance Analyst works with coaches on a daily basis to help find performance improvements in each specific performance area. The study conducted by Bryant, et al. (2018), within an Olympic/Paralympic high-performance environment, demonstrated the importance of sport scientists finding innovative ways to contribute new knowledge and innovations for coaches to use to help prepare athletes for major competition.

Multidisciplinary approach to PA

This study aimed to adopt a multidisciplinary approach to PA within NZ Track Cycling. However, this was only partially met during the research conducted. The aim of addressing all areas of the technical, tactical, physical and psychological aspects of the Team Pursuit and bringing the information together was not completed. Technical and tactical elements were introduced well. This can be seen in the positive feedback from the coaches. However, physical areas of analysis were not aligned, nor were the psychological area of sports science. In Cycling New Zealand, there is support in all aspects of performance, with experts working in all areas of sports science. Collaborating and combining information is a current limitation in the Cycling New Zealand organisation. Small pockets of collaboration occur but if collaboration of information was to improve this could benefit performance in Cycling New Zealand. The findings of this study suggest that PA and Video are areas of sport science support that can be a focal point for sport science collaboration. In an environment such as elite sport, that is highly competitive for athletes, as well as staff, multidisciplinary teams can be a positive influence on the working environment, cooperation and collaboration (Reid, et al. 2004).

The collaboration of PA, coaches, sports scientists and other areas of support providing data, can be instrumental in the development of informed practice (Bartlett, & Hughes, 2002). Wilson, (2008) argued that multiple areas of sports science that can benefit from the use video to analyse performance. Physical conditioning, physiology, psychology and nutrition were all areas of sports science can analyse performance through video. There is a need moving forward to continue to work on the multidisciplinary approach to PA and how it can benefit other areas of sports science as well (Glazier, 2010). Glazier, (2010) argues the need for a multidisciplinary approach to PA. The combining of different areas of sports science such as biomechanics and notational analysis has attracted criticism from researchers (Bartlett, & Hughes, 2008; Bartlett, 2001) but areas such as biomechanics, notational analysis, physiology and psychology can conduct PA in different ways. The research in Cycling New Zealand supported the Glazier multidisciplinary approach and attempted to combine the areas of technical, tactical, physical and psychological together to help effectively inform performance.

Similar to findings from previous literature in this areas (e.g. Gabbett, & Ryan, 2009); Kolmann, Kramer, Elferink-Gemser, Huijgen, & Visscher, 2018; Wheeler, Wiseman, & Lyons, 2017), technical and tactical elements of Track Cycling were more easily combined than adding physical and psychological elements to PA. Developing a shared vision and working model amongst support areas, for the process of multidisciplinary collaboration, and having open communication with other areas of support is an area that could help to bring physical and psychological elements into research in the future (Reid, et al, 2004).

The findings of this study identified that one area of support within Cycling New Zealand that could benefit from this collaboration is the physical areas of analysis. Aligning the quantitative data from the athlete bikes, with the qualitative information gathered in PA will allow more informative feedback to be given. This study demonstrated that is important to provide meaning to how quantitative data is applied to PA (Carling, Collins, & Wright. 2014). Analysing the technical aspects of video, numbers could be used to gather a bigger picture of how a Team Pursuit change can occur during performance. Using video analysis, Faiss, Maier, & Sigrist (2017) found that lead time on the front of the team pursuit was 18.1 ± 3.6 seconds, transition time moving above and below red line was around 3.3 ± 0.3 seconds and transitions started approximately 24.7 metres into the curve and lasted approx. 78.3 metres. These numbers add to the visual analysis from video and create an overview on what an ideal Team Pursuit change can look like. This can help coaches and analysts create an picture of what an ideal change could look like and whether the athletes are using the bankings in the Velodrome in a way that will keep power metrics and aerodynamic positioning in the best possible range.

The Importance of Feedback

Even the most basic feedback and information can be useful in the support of the coaching process (Carling, Collins, & Wright. 2014). The focus of this project was founded on coaching feedback and developing PA to be able to help the feedback process on performance objectives more effectively. Making sure, during the study, that performance objectives remained the same and were communicated, as well as allowing the coach to give feedback on the changes and improvements in PA, helped to retain a strong relationship between coach and analyst. Coach philosophy plays a big role in performance objectives and the areas of interest to a coach. Bryant et al. (2018) found that 90% of PA's indicated that coach philosophy or experience impacted on the analysis and direction of analysis that was done. It was suggested that the ability for Performance Analysts to communicate coaching philosophies into variables and behaviours that can be analysed, is an important aspect of the PA process. Following on from this, it was found that an effective coach-analyst relationship where both parties can contribute views and knowledge was the best guide to PA provision (Bryant et al. 2018).

PA is an integral tool in the coaching process by helping provide effective and accurate feedback. In the study conducted by Bryant et al. (2018), PA participants found that video formed the foundation of PA provision. The main change or improvement made in the DSR process of the study was centred around video. Adding multiple camera angles to the PA system and design was seen by the analyst and from the performance objectives, as a way of helping the coaching feedback process. This was also seen in the feedback gathered from coaches, the three camera views helped with feedback by providing more visual information on the performance objectives from different angles and provided more information on looking at aerodynamic positioning as well as line formation of the Team Pursuit.

Accurate and timely feedback is seen as a critical aspect in professional sporting environments (Atkins, Jones, & Wright, 2012; Cushion, & Groom, 2005). 75% of elite professional and semi-professional UK coaches who took part in the study conducted by Atkins, Jones, & Wright (2012) found that time was a main limiting factor for feedback to be given. Through other areas of research it is was also found that the main constraint with PA is time available and quantity of feedback (Bryant, James, Nicholls, & Wells. 2018; Giblin, Parrington, & Tor, E. 2016). In the Cycling New Zealand training environment, having timely video feedback for athletes between efforts is seen as very important for feedback. Developing a three camera view system that still allowed this to happen was a crucial part of the decision making process of the project. Creating a post session review option was also crucial, to take away the time factor in a session and allow coaches and athletes the option to analyse footage and information online at any time. The online platform of Hudl™ allowed this to happen.

Software and Hardware

The advances in software and hardware technology have allowed sports scientists to measure key aspects of performance that previously have been confined to a laboratory setting. Given the large array of tools available in the area of technology and sport and the desire for more in-depth information to be collected rapidly, coaches and applied scientists need to be careful in selecting the appropriate technology tools needed (Giblin et al. 2008). During this research, it was important to stay focused on the aims and objectives of the study when looking into technology changes. The outcomes of this project at Cycling New Zealand aligned with the findings from Corley, et al. (2015), who supported the use of video as a tool which allows coaches to review, reflect and evaluate the development of athlete preparation for a major race, both qualitatively and quantitatively. The introduction of three camera views and an online video platform made review, reflection and evaluation even more significant to the coaches and provided them with the tools to analyse athlete performance in depth. Combining several video camera views and video from the front, side and back views, coaches can have several different perspectives of an athletes performance that wouldn't be seen by normal observation (Wilson, 2008). The online platform made viewing footage and information more accessible. The new system also allowed for feedback to be given rapidly in a training session, or the video could be edited, processed and reviewed for post session feedback online (Corley, et al. 2015). As well as providing the video platform for training video analysis, it can also be utilised for competition analysis. This aligns with Wilson (2008), who stated that video playback options available allow coaches the ability to analyse and review a performance post event, allowing the coach to focus on the particular aspects of an athlete's performance during the actual event (Wilson, 2008).

Video software capture options investigated included software packages such as Sportscode™, Dartfish™, Nacsport™, Quintec™, Angles™ and Piston™. All of these video capture options offer a different range of capturing footage and analytical tools to analysis performance. Sportscode™ was identified as the video capture software that offered the "best fit" capturing abilities and analytical tools for Cycling New Zealand. It was also what was originally used in Cycling New Zealand so was an easy option to continue to work with. Sportscode™ offered multi view camera capturing, analytical tools such as overlay of footage and frame by frame movement, and Sportscode™ also had a direct link into the Hudl online platform to make accessibility and upload speed considerably greater. The cost of Sportscode™ was a problem as it almost doubled what other software products were in price. Technology works on a moving scale with low cost and easy to use measurement tools to expensive more sophisticated data (Giblin, et al. 2008). Quality of technology also falls on that spectrum with the more expensive "gold standard" products usually producing the best quality measurements, footage or data (Gilbin, et al. 2008). Due to limited funds in the PA space in Cycling New Zealand the cost of Sportscode™ was a limitation. However, its ability to provide options for multi camera views and analytical tools made the systems and design changes an easier process than other software options. In the survey that was conducted with UK elite professional and semi-professional coaches, by Atkins, et al. (2012), it was shown that Sportscode™ was the software over half of the coaches had access to (59%), with Dartfish™ secondary with 23%. This could show that even though the cost of Sportscode™ is great, the quality and ease of the software product is unlike others in its field.

PA interfaces have become a fundamental tool for coaches and applied scientists to aid the set-up of equipment, the process of data collection and the provision of feedback (Giblin, et al. 2008). Corley, et al.

(2015) investigated the use of video capture options, camera selection, camera configuration, data processing and feedback options in swimming. These five areas were also investigated in Cycling New Zealand to examine whether the "best fit" interfaces and products were being used to help provide the feedback needed. The key aspects of camera choice and specifications were investigated, with motion blur (shutter speed), frame rate and resolution explanations and equations discussed in depth. High-speed cameras, for video analysis can be regarded as one of the most versatile tools for frame- by-frame analysis of athletic motion. Current technology allows engineers to design camera systems with manual options for users to control settings, all at reasonable prices (Puao, 2016). Although from a financial viewpoint a high speed camera could not be purchased at Cycling New Zealand, due to limitations on funding in PA, the concept of manually controlling settings such as motion blur, frame rate and resolution was important in this project. Track cyclists move at speeds between 50 – 80km/h and being an indoor sport, lighting limitations can have an impact of video quality. Being able to manually select the appropriate settings to work with high speeds and low lighting is crucial. The camera selection and configuration was investigated against what was originally used at Cycling New Zealand. Configuration such as shutter speed, frame rate and resolution were tested, which was similar to that of Corley, et al. (2015), who looked at the suitable frame rate and shutter speed needed in swimming. Equations on suitable shutter speed, frame rate and resolution were conducted, using the equations set by Puao (2016). Minimum specifications were 50 frames per second, a shutter speed of 600 and a resolution of 720p. Faiss, et al. (2017), looked at qualitative video analysis in Track Cycling Team Pursuit and also found the use of 720p HD resolution footage to be suitable for Track Cycling.

DSR framework and process

A DSR approach is a great model to follow to investigate the problems identified for research. It is fundamentally a problem seeking paradigm (Karmokar, 2013) and focuses on solving problems, through the use of a rigorous research and evaluation processes. There are limited mental models or templates for researchers to evaluate against in DSR. Bragge, et al. (2006) found this gap in DSR research and created a model to guide researchers in DSR and provide a mental model to show what a DSR output can look like. An adapted Bragge, et al. (2006) model was used to guide the DSR process in this project. The DSR model was then applied to the elite sporting context and explored as a way to implement changes in systems and design, which is an unknown area for PA in sport. The DSR process and the adapted model from Bragge, et al. (2006), gave the PA systems and design investigation a good structure and was an easy to use model. As stated by Chatterjee, & Hevner (2010), DSR focuses on creativity in the design and construction of artefacts that have a place in application environments. PA, being an applied area of work, fits in with this environment. Having clear stages of problem identification, objectives of solution, design and development, demonstration, evaluation and communication, created a foundation for the project. The ability with the DSR process to be able to go back and further change and re-create the artefact and design had an impact with the PA investigation. It allowed evaluation to be done into the original systems and design of PA in Cycling New Zealand, to investigate new software and hardware to help align PA with performance objectives, and then further investigation to be done into future directions in PA at Cycling New Zealand. It was a process that worked well in the changing environment of high performance sport and PA.

Few studies have looked at how PA systems are designed and delivered to meet the needs of a specific sport. Corley, et al. (2015) conducted a systematic review of video-based methods for competitive swimming analysis. Likewise, Carling, Collins, & Wright (2014) looked into the effective, practical and conceptual use of PA. Both studies however, did not implement changes that were suggested. The PA investigation in Cycling New Zealand found problems in current systems and design but unlike the studies above, DSR process model helped form a framework for implementing improvements and changes for Cycling New Zealand.

There are limitations that were found from using a DSR model, as well as the DSR process itself. One of these was the use of DSR in sport as a new approach to investigating PA. The DSR approach to investigating PA is new to sport and having no model or process to follow made the process difficult. This was due to the minimal research guidance with models of this nature in sport. The research in DSR heavily surrounds IT and technology-based disciplines, as well as design projects, making the artefact builds and design to be highly different to what was done in this project. DSR is a problem-solving paradigm that focuses heavily on the design and build of an artefact, rather than organisational contexts. While this was seen as a positive at the beginning of the project, as it brought the focus solely on PA and the systems and design, having more feedback from external sources would have added more depth to the project. In a study by Cotterill, et al (2019) focussing on elite athletes and their engagement with training monitoring systems, nine female sprint athletes gave feedback on the use of training monitoring systems over a 12 month period. From the study, 78% of the athletes involved were either undecided or disagreed that they received enough feedback from the training data. 44% of participants also agreed or strongly agreed that training monitoring feedback did in fact optimise training and performance. Through the feedback gathered from the athletes in the study by Cotterill et al. (2019), a better picture can be seen on the impact analysis systems such as training monitoring systems, can have on athletes and how they interact with them. Within Cycling New Zealand, adding athlete perceptions to the study could bring a better overall picture of how the new systems and design is used for PA and whether it is effective in helping with feedback for performance objectives, from an athlete perspective. It can provide detail on whether the system is easy to use for athletes, adds more depth to feedback and whether changes need to continue to occur to improve the system and design in PA.

Communication and Buy-in

Having performance conversations with coaches was an important part of this research, in order to gather information on Team Pursuit performance objectives. These conversations allowed an understanding to be developed on how PA systems and design can be applied to more effectively benefit the coaching process. Bryant, et al. (2018) found that developing an understanding on how PA services can effectively be implemented is a considerable opportunity for applied practitioners. This open communication is important for PA's. Martindale and Nash (2013) found that, along with lack of resources and opportunities, inconsistency of understanding was one of the barriers to coach engagement in sport science within sporting contexts. Martindale, & Nash, (2013) discussed the sports science relevance and application from the perceptions of UK coaches, which can also be applied to the area of PA. The key findings showed there was a variation that exists between coaches and the understanding of sports science and its application. Coaches interviewed in the study found that although applied research suggests sports science adds considerable value to the performance enhancement process (Reid, et al, 2004), a sports scientists ability to apply knowledge effectively was a major barrier (Martindale, & Nash, 2012). During the investigation in PA at Cycling New Zealand, establishing performance objectives and identifying the areas that needed to be targeted for performance was important to begin the project. Moving forward, it was important to make sure the knowledge was applied into the new PA systems and design to allow an effective application of PA and coach buy-in. It is crucial that sport scientists understand the needs of a sport before applying specialist knowledge (Martindale, & Collins, 2005). This can also be applied to the field of PA and applying qualitative and quantitative information into sport.

The coaches were an integral part of the DSR process in this research. Feedback was gathered from the coaches on any changes or improvements made during the DSR process, which allowed understanding to grow on how the PA systems and design were impacting on feedback and coaching. This started conversations on performance objectives and whether the information and feedback was targeted in the right area of performance. It was found that coaches and the environment in high performance sport often changes, with the introduction of new coaches and new athletes happening often. Performance objectives had to be re-visited at multiple stages of the research to make sure all Team Pursuit athletes were still targeting the original performance areas discussed.

In this study, the researcher-analyst encountered some challenges in engaging coaches in discussions around PA and video, such as changes in coaching personnel, limited time in the schedule to interview coaches, and limited direction provided by some coaches regarding their needs for PA. The research aligned with the findings of Bryant, et al. (2018), that found there was a lack of information regarding the value of PA and feedback from a coaching perspective. Making sure the coaches were providing feedback and the area of PA understood performance objectives was very important. Recipient buy-in was found by Bryant et al. (2018) to be impacted by the regular use of video in full form, within current practice. Like any area of sport science, is clear that the effectiveness of PA is affected by coach buy-in to PA (Reade, Rodgers, & Hall, 2008). Following the meeting when the findings of the study were fed back to the coaches, greater buy-in was observed in PA support by the coaches, and subsequently the athletes. It could be argued that with multiple sport scientists competing for coaches' attention, buy-in to PA, and any area of sport science, will be influenced by coaches' perceptions and the importance they place on each area. PA is a relatively new area of sport science support (Mackensie & Cushion, 2013), and is establishing itself within high performance environments. Given this, barriers may remain to it being established as a well-used and well-understood area of sport science. It is argued that greater coach education is needed regarding PA within elite sport. Given that coaches often learn from and reflect with other coaches in order to identify new knowledge (Reade, Rodgers, & Spriggs, 2008), the findings of this study support close collaboration between PA and coaches in identifying ways to achieve marginal gains within cycling.

Collaboration can help to maintain strong communication, problem solving and prevent competition between staff. It can also help to limit closed and hierarchical conversation which can prevent information sharing throughout a high performance team. Reid, et al, (2004) discussed conflict and limitations that can cause barriers in multidisciplinary approaches to elite sport. Collaboration and the importance of this, from a sports science perspective, was also discussed.

The key findings in developing a collaborative sports science environment were:

- Developing a shared vision and working model for the process of multidisciplinary collaboration
- Developing trust and an environment where change is viewed as necessary to achieve
- Creating an atmosphere that accepts mistakes
- Encouraging open communication

These findings above, for collaborative environments, could be addressed in future to help Cycling New Zealand continue toward a multidisciplinary approach to PA and athlete support.

Alongside the coaches, the buy-in of athletes is also an important area for consideration in PA. Athletes and staff in high performance culture are confident in their abilities and can be sceptical about the value of new approaches or different regimes (Eubank, 2014). Poor athlete buy-in can be problematic and by understanding the perspectives of the end user with PA/feedback, evidence based strategies can be used to improve user buy-in and engagement (Cotterill, Jobson, & Neupert. 2019). The buy-in of athletes was explored in this project with the introduction of a new online video platform. The Hudl ™ online video platform was introduced to allow athletes (and coaches) the opportunity for pre/post training and competition analysis of technique, as well as tactical analysis in other endurance events in Track Cycling. Buy-in was again the key to integrating PA into the environment (Reade, Rodgers, & Hall, 2008). The process of introducing the new PA system was approached by allowing the coaches to use and see value in the online platform, before introducing it into the athletes training and competition environments. After the coaches saw value in the platform it became part of the training analysis and feedback process for them, as well as the athletes. Coaches asked the athletes to complete homework and allowed them to watch the video of training from home rather than track side during a training session. This was positively received by the athletes and engagement was high.

Compared to the low levels of engagement in PA observed at the start of the study, this marked a real change in approach by the coaches. While the coach remained in control of the feedback process, there was now a focus on 'athlete engagement'. Athlete focused approaches to PA and video feedback have found support elsewhere in elite sport research (Groom et al, 2011; Middlemas & Harwood, 2018; Nelson et al, 2014). Through coach buy-in and use of the Hudl™ online platform, athletes became familiar with the system and it is now part of the post training and competition PA system. The athletes could use more time away from training to look at technique and take feedback from coaches during a training session and review where improvements needed to be made. In training it allowed for less focus to be on feedback after each training rep. Hudl™ gave the ability for the whole squad or just individuals to look at video and gain confidence in team and individual performances. This is similar to findings from Cushion, & Groom, (2005) where video aided recall, helped to develop understanding, encouraged athletes to self-critique, provided athletes with an opportunity to reflect on performance without emotions and helped to improve player confidence. The study by Wright et al. (2013) also found that video helped with individual reflection and enabled understanding of performance from more of a holistic view.

Strengths and Limitations of the study

Buy-in through the introduction of a new PA system, the online video platform was a significant strength to the research. Post training video reviews of performance did not happen previous to the introduction of the online video platform at Cycling New Zealand. Video-based PA would be analysed during a training session, in between training reps, which limits feedback discussions and the focus of the session. Having an online platform where athletes and coaches can go to view training and competition footage, analyse performance and review video has been a well-used addition to PA at Cycling New Zealand. The initial buy-in from the coaches allowed the online platform to be trialled well and for value to be seen in the process of post training review. Coaches then brought the use of the online platform into the analysis and feedback process for the athletes through homework tasks or specific areas of focus to give feedback back to the team and coach on.

Another strength of the research was the DSR model and process adapted from Bragge, et al. (2006). The model created a clear guide of how to investigate PA in cycling. The process of problem identification, objectives of solution, design and development, demonstration, evaluation and communication created a step by step solution as to how to proceed in designing a new system for PA in Cycling New Zealand. The DSR process is a new approach to use in sport but is well suited to building and/or creating new design and systems. Having a new framework, such as the DSR model, to implement changes in PA and other support areas, is a good addition into research in elite sport. A further strength in the research was applying PA to coach performance objectives. It is an important part of investigating and changing systems and design in PA. Performance objectives set by the coaches are what drives feedback to the athletes. Making sure these align with the PA that is being done allows more accurate and beneficial feedback to be given in the coaching process. A positive analyst and coach relationship helped to achieve this during the project. Good communication on the positives and negatives in the area of PA and gathering detailed coach feedback helped the DSR process and future directions for PA at Cycling New Zealand.

While potential barriers to using DSR were identified (e.g. funding), the coaches seemed to prefer the fast, informal research dissemination that DSR offered compared to the slow, quality control approach of lab-based research that is typical within sport science settings (Malone et al., 2019). Given the pressures of integrating new ideas within the short cycles between major competitions, DSR, with its applied focus and coach buy-in, seemed to offer much to the elite sport environment.

One of the main limitations in the research was the time available to conduct research and trial products in the Cycling New Zealand environment. Due to the fast approaching first Olympic qualifying events and the need for athletes to focus in on execution of performances, rather than technical information in depth, there was a small opportunity to trial and demonstrate new products during training and gather feedback from coaches. More time was needed to fully explore each potential software package and hardware camera option before making a decision on which pathway to take. Only the key software packages of Dartfish™, Piston™ and Sportscode™ were demonstrated in the training environment, with only two different types of IP cameras and hardware. These products were chosen on the specifications that were met but also selected on recommendations from other Performance Analyst's in New Zealand who had used these software packages and IP cameras before.

Having a small feedback group was another limitation in the research. A strength of the DSR process is that it allows for the design and build of the new technology or system to be the main element in the process. The focus is on the design and build and not the organisational context or end user. Athletes are one of the key users of PA and video-based feedback. Having greater feedback from the athletes would allow more buy-in to the PA process and help to change or improve more aspects of the PA systems and design to suit the feedback process, based on the performance objectives. The coaches feedback was instrumental in the future direction that this DSR project will have. Allowing athletes the chance to add to this feedback would grow more depth into the decision making process.

Practical Considerations

The DSR model for the research, was adapted from Bragge et al. (2006). The model had six clear stages of problem identification, objectives of a solution, design and development, demonstration, evaluation and communication. The six steps in the model by Bragge et al, (2006) were easy to follow for the first study to apply the concept of DSR to elite sport. Coaches and relevant staff at Cycling New Zealand were also able to follow the process of DSR with ease and understand the process that took place in the investigation. Models such as Hevner, et al. (2004) have a more complex approach which consists of design of an artefact, problem relevance, design evaluation, research contributions, research rigor, design as a search process and communication of research. While Hevner, et al. (2004) are well recognised in DSR research, the model brought a more complex view to the DSR process. Exploration of the DSR concept in elite sport needed a basic introduction to allow for easy explanations, application and use. This was achieved in this research.

To optimise the impact of the DSR process, all phases of the model need to be delivered well. In this study, the demonstration phase of the DSR process was not conducted as well as it could have been. In future, improvements could be made to ensure all potential systems and design are demonstrated thoroughly. Due to timing and access to hardware and software products, only a few of the products were demonstrated in the training environment. Decisions were made from specifications found on the products without testing in detail. While Sportscode™ was chosen as the software package to move forward with, it is acknowledged that there was a bias due to already having the software in Cycling New Zealand and the ease of not having to transfer over to another software provider became evident in the study. Making sure there is enough time to fully demonstrate and evaluate each option, moving forward, is an important consideration for practitioners adopting DSR. Along with testing, feedback with coaches needs to be conducted frequently. PA is used to compliment feedback for coaches (Corley, et al., 2015), meaning coach perspectives are instrumental in testing new products that could help to benefit the feedback process. Feedback from athletes could add more depth to the PA systems and design feedback, and allows other concerns or issues to arise from an athlete perspective during the DSR process.

Practitioners and researcher also need to reflect carefully on the focus of their PA systems before engaging in DSR. There are barriers which need consideration. There is a potential trade-off between gold standard (top quality) and what is practically possible for the program to get/achieve with technology and PA. This was a major factor in this project. Cost is a major barrier to getting gold standard industry products (Giblin, et al. 2016). Due to limitations in budget, being able to get the most functional, easy to use software and hardware that meets all the needs of Cycling New Zealand and beyond, was impossible. The trade-off between gold standard and what is practically possible is an important point to remember when looking into systems and design changes. At multiple stages in the project, such as software choices and the ability to purchase multiple computers and hardware, the cost factor became a major barrier and other options had to be investigated that could deliver a similar outcome but with minimal cost. Contracts and Obligations to Sportscode™ also created time barriers if the option was to look elsewhere for another software. The long process of moving away from Sportscode™ and the time that would of taken was not a practical process that was able to happen. The investigations into other software that are potentially more cost effective and show the same benefits as Sportscode™, are possibilities that can be considered in the future, when time is a lesser constraint.

Future Directions

Further research is needed within applied settings to understand how to integrate multidisciplinary areas such as physical data to PA. As time was limited with a new Olympic qualification season approaching, limited DSR rounds could be undertaken. The chance to involve physical data into the technical and tactical information provided was limited. Future directions in Cycling New Zealand and the DSR process, with the implementation of more multidisciplinary areas of PA, may be continued moving forward. The integration of physical data to

PA information can grow more depth to feedback and help toward aligning the systems and design of PA with the performance objectives of coaches. The collaboration with sports scientists and coaches to gather the physical data can also help grow strong relationships and communication in the Cycling New Zealand Track Cycling program. The physical data that could add specific value to the new systems and design could consist of height and length of a Team Pursuit change, power produced at start, middle and end of a Team Pursuit change and aerodynamic figures that look at how well an athlete is positioned on the bike during a Team Pursuit effort. The process of developing a model on what an "ideal change" looks like in Team Pursuit is an area that will be of great benefit toward marginal gains needed in top level performances. The combination the technical element of a Team Pursuit of where to start a change and the height it should be performed to, the tactical element of which lap an individual should complete a change, the physical elements of power, distance and time, as well as the psychological aspects of consistency, will all be crucial elements to help toward building a model for Team Pursuit changes.

The implementation of changes to systems and design in other sports can be done through utilising the DSR model approach. The model allows for a simple, easy to understand framework that can help guide the process of changing or improving aspects of the sporting environment. Evaluation of systems and design in sport often occurs but the future directions and key findings are never implemented. With the introduction of the DSR process into a sporting context, the further steps of implementation can occur with ease. The process allows for all relevant staff involved to understand each step because of the simple but easy to apply nature of the model. DSR can be applied to multiple areas of PA, such as physical, psychological, technical and tactical.

While there has been exploration into the coach interaction with PA and the perspectives coaches hold on the use of PA, (Martindale, & Nash, 2012: Reade, et al. 2008) athlete perspectives could be investigated in future research. Feedback from athletes on the systems and design of PA and how this affects learning could add great depth to research in this area. Athletes receive the feedback and analysis of performance, so to have a system and design that is both easy to present and easy for athletes to understand is important.

Conclusions

The aim of this thesis was to investigate the use of video and PA systems in the Track Cycling environment in New Zealand. PA is an important part of the coaching feedback process. It provides objective data to inform and support the coaching process and is an integral tool within the coaching (Byrant, et al. 2018). In a high performance environment, that relies on good performances for funding, high levels of pressure and stress to perform well are very common (Gould, Gruinan, Greenleaf, & Chung, 2002). Having a PA system and design that create ease with feedback and helps coaches and athletes toward marginal gains in performance can be instrumental. In this project within Cycling New Zealand, investigating the use of video and PA systems in the Track Cycling environment, aligning PA systems and design with coach led performance objectives, was a step toward helping with marginal gains. Through the problem-seeking paradigm of the DSR process, a clear investigation process helped to guide changes and improvements in PA. The exploration of a new model, such as the DSR model, has created great opportunity in the future for other researchers in elite sport to utilise this approach. The introduction of multiple camera views and an online video platform were changes made to the PA process at Cycling New Zealand with buy-in from coaches and athletes, as well as behaviour change had to occur to make these changes possible. Through a strong Performance Analyst and coach relationship, communication and good feedback allowed for changes to occur and future directions to be found through the project. The investigation into PA in Cycling New Zealand and the effectiveness of the systems and design, has set the process in motion of collaboration between different areas of sports science. The multidisciplinary approach to PA (Glazier, 2010) and continuing to combine technical, tactical, physical and psychological areas of sports science together for PA has begun with this project and will help to guide future direction in PA at Cycling New Zealand.

Chapter Five: References

Abbiss, C.R., Mackay, K., & Penaillo, L. (2018). Rate of perceived exertion during concentric and eccentric cycling: Are we measuring effort or exertion? *International Journal of Sport Physiology and Performance,* 13(4), 517-523. doi: 10.1123/ijspp.2017-0171.

Atkins, S., Jones, B. & Wright, C. (2012). An analysis of elite coaches engagement with performance analysis services (match, notational analysis, technique analysis). *International Journal of Performance Analysis in Sport,* 12(2), 436-451. doi: 10.1080/24748668.2012.11868609.

Bampouras, T., Cronin, C. & Miller, P. (2012) Performance analytical processes in elite sport practice: An exploratory investigation of the perspectives of a sport scientist, coach and athlete. *International Journal of Performance Analysis in Sport,* 12(2), 1-10. doi: 10.1080/24748668.2012.11868611.

Barker, J., Davis, K., McKinney, E., & Smith, D. (2004) The role of communication values in swift starting action teams: IT insights from flight crew experience, *In- formation & Management,* 41(8), 1043-1056. doi: 10.1016/j.im.2003.10.006.

Barris, S., & Button, C. (2008). A review based motion analysis in Sport. *Sports Medicine*, 38(12), 1025-1043. doi: 10.2165/00007256-200838120-00006.

Barlett, R., & Bussey, M (2012). *Sports biomechanics:* Reducing injury risk and improving performance. London: Routledge.

Bartlett, R., & Hughes, M. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences*, 20(10), 739-754. doi:10.1080/026404102320675602.

Bartlett, R., & Hughes, M. (2008). What is performance analysis? In: Hughes, M. & Franks, I. (eds.) *The Essentials of Performance Analysis: An introduction.* London: Routledge, 8-20.

Barrat, P. (2008). SRM Torque analysis of Standing Starts in Track Cycling. *The Engineering of Sport,* 1(7), 443-448. doi: 10.1007/978-2-287-09411-8_52.

Batsche, C., Boyer, E., Miltenberger, R., & Fogel, V. (2009). Video modeling by experts with video feedback to enhance gymnastics skills. *Journal of Applied Behaviour Analysis,* 42(4), 855-860. doi: 10.1901/jaba .2009.42-855.

Bernhardsson, L., Haj-Bolouri, A., Purao, S., & Rossi, M. (2017). *Action Design Research as a Method-in-Use: Problems and Opportunities*. In: Maedche, A. vom Brocke, J. Hevner, A. (eds.) Designing the Digital Transformation: DESRIST 2017, Research in Progress Proceedings of the 12th International Conference on DSR in Information Systems and Technology, pp110-118.

Blocken, B., Carmeliet, J., Defraeye, T., Hespel, P. Koninckx, E., Nicolai, B., Verboven, P. (2013). Cyclist drag in team pursuit: influence of cyclist sequence, stature and arm spacing. *Journal of Biomechanical Engineering*, 136 (1), doi:10.1115/1.4025792.

Bragge, J. Gengler, C. Hui, W. Peffers, K. Rossi, M. Tuunanen, T. & Virtanen, V. (2006). *The DSR process: A model for producing and presenting information systems research.* International Conference on DSR in Information Systems and Technology DESRIST.

Brannick, T., & Coghlan, D. (2005). *Doing Action Research in your Own Organization*. London: Sage Publications, (6), 3-21.

Bryant, E., James, N., Nicholls, S. & Wells, J. (2018) Elite Coaching use and engagement with performance analysis within Olympic and Paralympic Sport. *International Journal of Performance Analysis in Sport,* 18 (5), 764-779. https://doi.org/10.1080/24748668.2018.1517290.

Butt, J. Hays, K. Maynard, I. Olusoga, P. (2012). Coaching under pressure: A study of Olympic coaches. *Journal of Sports Sciences,* 30(3), 229-239. doi: 10.1080/02640414.2011.639384.

Butterworth, A. Cropley, B. & O'Donoghue, P. (2013). Performance profiling in sports coaching: a review. *International Journal of Performance Analysis in Sport*, 13 (3), 572-593. Doi:10.1080/24748668.2013.11868672.

Carling, C., Collins, D., & Wright , C. (2014). The wider context of performance analysis and its application in the football coaching process. *International Journal of Performance Analysis in Sport*, 14 (2), 709-733. doi: 10.1080/24748668.2014.11868753.

Chatterjee, S., & Hevner, A. (2010). Design Research in Information Systems: Theory and Practice. Springer: Berlin.

Craig, N.P., & Norton, K.I. (2012). Characteristics of Track Cycling. *Sports Medicine*, 31(7), 457-468. doi: 10.2165/00007256-200131070-00001.

Corbett, J. (2009). An analysis of the pacing strategies adopted by Elite Athletes during Track Cycling. *International Journal of Sports Physiology and Performance,* 4(2), 195-205. doi: 10.1123/ijspp.4.2.195.

Corley, G., Godfrey, A., Osborough, C., Olaigin, G. Mooney, R., & Quilan, L. (2015). Application of video-based methods for competitive swimming analysis: A systematic review. *Sport Exercise Medicine Open Journal*. 1(5), 133-150.

Croft, H. Middlemas, S. & Watson, F. (2017). Behind closed doors: The role of debriefing and feedback in a professional rugby team. *International Journal of Sports Science and Coaching*, 0 (0), 1-12. doi: 10.1177/1747954117739548.

Cotterill, S. Jobson, S. Neuport, E. (2019). Training- Monitor Engagement: An Evidence-Based Approach in Elite Sport. International Journal of Sports Physiology and Performance, 14(1), 99-104. doi: 10.1123/ijspp.2018-0098.

Cushion, C., & Groom, R. (2005). Using of video-based coaching with players: A case study. *International Journal of Performance Analysis in Sport,* 5(1), 40-46.

Cushion, C., Groom, R., & Nelson, L. (2011). Analysing coach-athlete ‘talk in interaction’ with the delivery of video-based performance feedback in elite youth soccer. *Qualitative Research in Sport, Exercise & Health,* 4(3), 439- 458.

Cushion, C., & Mackenzie, R. (2013). Performance Analysis in football: A critical review and implications for future research. *Journal of Sports Sciences*, 31(6), 639-676.

Doyle, C., Neville, K., & Sammon, D. (2016). A DSR (DSR) case study: building an evaluation framework for social media enabled collaborative learning environments (SMECLEs), *Journal of Decision Systems*, 25 (1), 125-144.

Day, J., Jordan, D., Kroeger, T., Neumann, F., & Wagner, M. (2011). Evolving Strategies for Team Pursuit Track Cycling. In: *9th Metaheuristics International Conference (MIC)*, 491–500.

Dijkshoorn, W., Heimans, L., Hoozemans, M., & Koning, J. (2017). Optimising the team for required power during Track Cycling team pursuit. *Journal of Sports Physiology and Performance*, 12, 1385-1391.

Dwyer, D., Machman, C., Ofoghi, B., & Zalenznikow, J. (2013). Modelling and analysing Track Cycling omnium performances using statistical and machine learning techniques. *Journal of Sports Sciences*, 31 (9), 954-962.

Faiss, R., Maier, T., & Sigrist, S. (2017). Qualitative Video Analysis of Track Cycling Team Pursuit in World Class Athletes. *International Journal of Sports Physiology and Performance*, 12(10), 1305-1309.

Fink, P.W., Foskett, A., Munro, L.A., & Stannard, S.R. (2017). Potentiation of sprint cycling performance: the effects of a high inertia performance ergometer warm up. *Journal of Sports Sciences*, 35(14) 1442-1450. doi: 10.1080/02640414.2016.1215492.

Franks, I., & Hughes, M. (2008). *The Essentials of Performance Analysis*. London: Routledge.

Franks, I., & Hodges, N. (2008). The provision of information. In: Hughes, M. & Franks, I. (eds). *The essentials of performance analysis: An introduction.* Abingdon, UK, Routledge.

Giblin, G. Parrington, L. & Tor, E. (2008) The impact of technology on elite sports performance. Sensoria: A Journal of Mind, Brain & Culture, 12(2). doi: 10.7790/sa.v12i2.436.

Gillis, A., & Jackson, W. (2002). *Research for nurses: Methods and interpretation*. Philadelphia, PA: F.A. Davis Co.

Glazier, P. (2010). Game, Set, Match? Substantive Issues and future Directions in Performance Analysis. *Sports Medicine*, 40 (8), 625-634. doi: 10.2165/11534970-000000000-00000.

Gould, D., Gruinan, D., Greenleaf, C. & Chung, Y. (2002). A survey of U.S Olympic coaches: Variables perceived to have influenced athlete performances and coach effectiveness. The Sport Psychologist, 16(1), 229-250.

Hanid, M. (2014). DSR as an Approach to Develop Conceptual Solutions for Improving Cost Management in Construction . Ph.D. Thesis, Retrieved from: http://usir.salford.ac.uk/32050/1/Final_Thesis.pdf

Hall, D. James, D & Marsden N. (2012). Marginal gains: Olympic lessons in high performance for organisations *HR Bulletin: Research and Practice*, 7(2), 9-13.

Hendricks, S., & Kraak, W., & Painczyk, H. (2017). Utilisation of performance analysis among Western Province Rugby Union Club coaches. *International Journal of Performance Analysis in Sport*, 17 (6), 1057 1072. doi: 10.1080/24748668.2018.1429757.

Herfridsson, O., O'Rossi, M., Purao, S., & Sein, M. (2011) History of Action Research. *MIS Quarterly*, 35 (1), 37-56. doi: 10.1.1.462.3275.

Hevner, A. (2007). A Three Cycle view of DSR. *Scandinavian Journal of Information Systems*, 19 (2), 87-92.

Hevner, A., March, S., & Park, J. (2004). Design Science in Information Systems research. *Management Information Systems Quarterly*, 28 (1), 75-105.

Hodges, B. Kuper, A. Reeves, S. (2008). Qualitative research: Qualitative research methodologies: Ethnography. *BMJ: Clinical research edition,* 337, 512-514. doi:10.1136/bmj.a1020.

Jones, A., Mauger, A., & Williams, C. (2011). The effect of non-contingent and accurate performance feedback on pacing and time trial performance in 4km Track Cycling. *Journal of Sports Medicine*, 45(3), 225-229. doi:10.1136/bjsm.2009.062844.

Karmokar, S. (2013). *Improving Website design process of SME's: A design science perspective.* Thesis submitted for: Doctor of Philosophy, Auckland University of Technology. Retrieved from: http://aut.researchgateway.ac.nz/handle/10292/5786

Laird, P., & Waters, I. (2008). Eyewitness recollection of sports coaches. *International Journal of Performance Analysis in Sport*, 8(1), 76-84. doi: 10.1080/24748668.2008.11868424.

Lewin, K. (1946). Action Research and Minority Problems. *Journal of Social Issues*, 2(4), 34-46. doi: 10.1111/j.1540-4560.1946.tb02295.

Lago, C., Leite, N., Gonçalves, B., Sampaio, J., & Victor, M. (2013). Effects of pacing, status and unbalance in time motion variables, heart rate and tactical behaviour when playing 5-a-side football small-sided games. *Journal of Science and Medicine in Sport,* 17(2), 229-233. doi: 10.1016/j.jsams.2013.04.005.

McGarry, T., O'Donoghue, P., & Sampaio, J. (2013). *Routledge Handbook of Sports Performance Analysis,* New York: Routledge.

McGuigan, M., & Vercoe, J. (2018). Relationship between strength and power production capabilities in trained sprint track cyclists. *Kinesiology*, 50(1), 96-101.

McHale, I., Moffat, J., Scarf, P., & Zhong, K. (2014). To lead or not to lead: analysis of the sprint in Track Cycling. *Journal of Quantitative Analysis in Sports*, 10 (2), 161-172. doi: 10.1515/jqas-2013-0112.

Minder, C., Nunamaker, J., & Purdin, T. (1991). Systems Development in Information Systems Research. *Journal of Management Information Systems*, 7(3), 89-106. doi: 10.1080/07421222.1990.11517898.

Mueller, P. Schumacher, Y.O. (2002). 4000m Team Pursuit cycling world record: Theoretical and practical aspects. *Medicine and Science in Sport and Exercise,* 34(6), 1026-1036. doi:10.1097/00005768-200206000-00020.

Pueo, B. (2016). High Speed Camera for Motion Analysis in Sports Science. *Journal of Human Sport and Exercise*, 11 (1), 53-73. doi:10.14198/jhse.2016.111.05.

Smith, & Sparkes. (2006) Narrative inquiry in Psychology: exploring the tensions within. *Qualitative Research in Psychology*, 3(3), 169–192. doi: 10.1191/1478088706qrp068oa.

Wilson, B. (2008). Development in video technology for coaching. *Sports Technology,* 1 (1), 34-40. doi: 10.10 02/jst.9.

Kawulich, Barbara B. (2005). Participant Observation as a Data Collection Method [81 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *6*(2), Art. 43, http://nbn-resolving.de/urn:nbn:de:0114-fqs0502430.

Malone, J. J., Harper, L. D., Jones, B., Perry, J., Barnes, C., & Towlson, C. (2019) Perspectives of applied collaborative sport science research within professional team sports, *European Journal of Sport Science*, 19(2), 147-155, doi: 10.1080/17461391.2018.1492632.

Reade, I., Rodgers, W., & Hall, N. (2008). Knowledge transfer: How do high performance coaches access the knowledge of sport scientists? *International Journal of Sports Science & Coaching*, *3*(3), 319-334. doi: 10.1260/174795408786238470.

Reird, C. Stewart, E. & Thorne, G. (2004). Multidisciplinary Sports Science Teams in Elite Sport: Comprehensive servicing or conflict and Confusion? *The Sport Psychologist,* 18(2), 204-217. doi: 10.1123/tsp.18.2.204.

Chapter Six: Appendices

Appendix 1: Information Sheet

Participation Information Form

Project Title: An investigation into the use of Video and Performance Analysis Systems in the New Zealand Team Pursuit track cycling squad.

General Information:
This study is being conducted to investigate the current video and performance analysis systems in the New Zealand track cycling squad. More specifically, it is looking at the use of video and performance analysis with the team pursuit discipline. Data collection will take place from approximately December 2018 – April 2019.
A design science research method will be used to evaluate the relevance and benefits of the current systems and make changes to both video and performance analysis systems, if needed. The changes made will be re evaluated and improved to continue to try and meet the needs of the team pursuit discipline. When satisfied that the video and performance analysis systems are of benefit and assisting the learning in the team pursuit, to the level needed, the design science evaluation cycle will come to an end. The findings will then be presented back to relevant CNZ staff.

Study aims and objectives:

- Investigate current Performance Analysis systems and video use in Cycling New Zealand track endurance program.
- Evaluate systems against Performance Analysis literature, using a Design Science methodology.
- Design and develop improvements in video and performance analysis systems to meet performance indicator feedback requirements of the endurance squad.

What will my participation involve?
Participation from endurance coaches is needed during the evaluation stage. This will be done by informal interview and will act as feedback. This feedback will help determine whether improvements/changes have been of benefit for team pursuit. The feedback will also provide information to determine whether need to be made to new systems or whether current systems are adequate.

Confidentiality and/or anonymity:
This study will only be presented internally to CNZ and will not be published or be presented externally. Although there are minimal coaches that will participate, feedback given will still remain anonymous.

Can you change your minds and withdraw from the project:
You can decline to participate in the study. If you agree to participate, you may withdraw from the study at any time and all information that you provided will not be used. To do so please contact Anna directly. This withdrawal can be done without reason and without disadvantage to you.

* If you have any questions or further information regarding the study please contact Anna at the below email address, by phone or in person. This can be now or at any point during the study.

Anna Higgins
0272886558
Anna.Higgins@cyclingnewzealand.nz

Appendix 2: Participant Consent Form

Participation Consent Form

Project Title: An investigation into the use of Video and Performance Analysis Systems in the New Zealand Team Pursuit track cycling squad.

I have read the participation information form and understand what the study is about. I understand that I can ask questions or for further information at anytime.

- My participation in this study is voluntary
- I can withdraw from the study at anytime without reason
- If I withdraw from the study it will have no disadvantage to me
- This study will only be presented internally to CNZ relevant staff. Not external publication or presentation will occur
- Participants feedback will remain anonymous

<u>I agree to take part in this study under the conditions below:</u>

□ I consent to participate in giving feedback on video and performance analysis systems when needed

□ I consent to participation in informal interviews on video and performance analysis

□ I consent to the use of direct quotes made by me in informal interviews and feedback sessions

.... *(signature of participant)*

.... *(date)*

.... (*signature of researcher*)

.... (date)

Anna Higgins
0272886558
Anna.Higgins@cyclingnewzealand.nz

Appendix 3: Interview Questions

<u>Questions for Interviews:</u>

1. Are you happy with the new system and changes made?

2. Are the changes and new systems easy to use?

3. Does it help you to provide improved feedback on performance objectives?

4. Any sugggestions for future improvements or changes?

Appendix 4: Ethical Approval

OTAGO POLYTECHNIC
Te Kura Matatini ki Otago

5 December 2018

Anna Higgins
14 Bernard Street
Tauranga South
Tauranga 3112

Dear Anna

Ethics: An investigation into the use of Video and Performance Analysis Systems in the New Zealand Team Pursuit track cycling squad

Thank you for your application.

We agree that you have addressed all of the issues we had concerns around and have approval to proceed with your research.

We wish you well with your study and remind you that at the conclusion of your research you should send a brief report with findings/conclusions to the Research Ethics Committee.

Yours sincerely

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Appendix 5: Hardware and Software Specifications of chosen products

Ultra Series | DH-SD56230V-HNI

DH-SD56230V-HNI

2MP 30x Starlight PTZ Network Camera

- 1/2.8" 2Megapixel STARVIS™ CMOS
- Powerful 30x optical zoom
- Starlight technology
- H.265 Encoding
- Max. 50/60fps@1080P
- Multiple video interfaces: HD-SDI, HD-CVI, DVI, HDMI, VGA, RJ45
- Support Wifi
- Support PoE+

H.265 | WDR | 0.005Lux | ICR D/N | PoE+

System Overview

Featuring powerful optical zoom and accurate pan/tilt/zoom performance, this camera provides an all-in-one solution for capturing long distance video surveillance for outdoor applications. Together with infrared illumination and Starlight Technology, the camera is the perfect solution for dark, lowlight applications. The series combines a day/night mechanical IR cut filter for the highest image quality in variable lighting conditions during the day, and True WDR for applications with direct sunlight or glare.

Functions

Starlight Technology
For challenging low-light applications, Dahua's Starlight Ultra-low Light Technology offers best-in-class light sensitivity, capturing color details in low light down to 0.005lux. The camera uses a set of optical features to balance light throughout the scene, resulting in clear images in dark environments.

Wide Dynamic Range
The camera achieves vivid images, even in the most intense contrast lighting conditions, using industry-leading wide dynamic range (WDR) technology. For applications with both bright and low lighting conditions that change quickly, True WDR (120 dB) optimizes both the bright and dark areas of a scene at the same time to provide usable video.

Auto-tracking
This feature controls the pan/tilt/zoom actions of the camera to automatically track an object in motion and to keep it in the scene. The tracking action can be triggered manually or automatically by defined rules. Once a rule is triggered, the camera can zoom in and track the defined target automatically.

High Efficiency Video Coding (H.265)
The H.265 (ITU-T VCEG) video compression standard offers double the data compression ratio at the same level of video quality, or substantially improved video quality at the same bit rate, as compared to older video compression technologies. H.265 offers such impressive compression by expanding the pattern comparison and difference-coding, improving motion vector prediction and motion region merging, and incorporating an additional filtering step called sample-adaptive offset filtering.

Environmental
Dahua cameras operate in extreme temperature environments, rated for use in temperatures from -20°C to +60 °C (-4°F to +140°F) with 95% humidity.

Protection
The camera allows for ±10% input voltage tolerance, suitable for the unstable conditions for outdoor applications. Its 4KV lightning rating provides effective protection for both the camera and its structure against lightning.

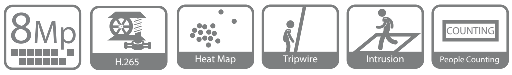
Interoperability
The camera conforms to the ONVIF (Open Network Video Interface Forum) and PSIA (Physical Security Interoperability Alliance) specifications, ensuring interoperability between network video products regardless of manufacturer.

www.dahuasecurity.com

DHI-NVR4104/4108-P-4KS2

4/8 Channel Smart 1U 4PoE 4K&H.265 Lite Network Video Recorder

- H.265/H.264 codec decoding
- Max 80Mbps Incoming Bandwidth
- Up to 8MP Resolution for Preview and Playback
- Up to 2ch@4K/8ch@1080P decoding
- HDMI/VGA simultaneous video output
- Support IPC UPnP, 4PoE ports



System Overview

Dahua NVR4000-4KS2 is introduced as the first Lite series NVR that supports for 4K and H.265 encoding technology with excellent performance at an affordable price. For applications where image details are highly required, it delivers the capability of 4K resolution processing. The NVR can be served as edge storage, central storage or backup storage with an intuitive shortcut operation menu for remote management and control.

Due to its cost-effective and easy-to-install design, this NVR is ideal for a wide range of applications such as public safety, water conservancy, transportation, city centers, education, and financial institutions.

The NVR is compatible with numerous third-party devices making it the perfect solution for surveillance systems that work independently of video management system (VMS). It features an open architecture that supports for multi-user access and is compatible with ONVIF 2.4 protocol, enabling interoperability with IP cameras.

Functions

4K Resolution

4K resolution is a revolutionary breakthrough in image processing technology. 4K delivers four times the resolution of standard HDTV 1080p cameras and offers superior picture quality and image details. 4K resolution improves the clarity of a magnified scene to view or record crisp forensic video from large areas.

High Efficiency Video Coding (H.265)

The H.265 (ITU-T VCEG) video compression standard offers double the data compression ratio at the same level of video quality, or substantially improved video quality at the same bit rate, as compared to older video compression technologies. H.265 offers such impressive compression by expanding the pattern comparison and difference-coding, improving motion vector prediction and motion region merging, and incorporating an additional filtering step called sample-adaptive offset filtering.

Intelligent Video System

Working with IVS-enabled IP cameras, the NVR recognizes and records video that contains IVS data on all IP channels. The NVR records standard intelligence at-the-edge features, as well as premium IVS features that detect abandoned or missing objects, Tripwire violations, and intrusion violations. The NVR is also capable of recording business analysis data – Facial Detection, People Counting, and Heat Map – from IP cameras with built-in Intelligent Business Analytics.

ANR (Automatic Network Replenishment Technology)

Network Video Recorders with the ANR function automatically store video data on an IP camera SD card when the network is disconnected. After recovery of the network, the NVR automatically retrieves the video data stored on the camera.

Easy4ip

The Easy4ip app is available on the iOS App Store and Google Play. It makes surveillance easy and simple, allowing you to remotely access NVR devices, view live video, receive event push notifications, and search for recorded videos from an iPhone, iPad, or Android phone at anytime from virtually anywhere!

TRUEN

TCS-3000

1080p60 Full HD Video Server

60FPS@1920 x 1080 · MPEG-TS Supported · Quadruple Streaming

2MP at 60fps full HD video server TCS-3000 provides various user interface which enables to perfectly use in various fields, such as sport and game broadcasting, and highway traffic status monitoring.

TCS-3000 can deliver H.264 video streams, at 60 frames rate in all resolutions up to full HD (1920 X 1080).
TCS-3000 also provides 3 different Input and Output formats, HDMI / Composite / 3G-SDI , which makes your choice wide.

TCS-3000 is perfect for small and large analog video installations, especially where an IP network infrastructure is already in place. Its small size also makes it ideal for use in discreet surveillance applications, for example, in retail stores and banks, and in camera housings.

Key Features

- 60FPS @ 1920 x 1080
- MPEG-TS Supported
- Quadruple Streaming
- Embedded Audio
- Dual Power (DC/PoE)
- ONVIF, PSIA Compliant