

Analysis of Speed Coaches Used in the Sport of Rowing

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ENGN2226

Systems Engineering Analysis

Australian National University

11 May 2015

Abstract

Speed Coaches are a valued piece of equipment used by rowers around the world. These devices provide rowers and their coaches with live data that is useful during training and races, and allows them to track their long term performance. Current Speed Coach models do not differ greatly from models of previous years, and remain expensive despite the continuously decreasing cost of the components and software. This portfolio took a systems engineering approach in order to analyse these current models of Speed Coach and identify areas where improvements could be made. Research was also undertaken to determine the views that rowers currently held in regard to Speed Coaches, providing a basis for this analysis. Undertaking this portfolio led to a list of 10 recommendations, which could be applied to the next generation of Speed Coach models. The recommendation that is expected to lead to the largest alteration in current designs is that wireless internet compatibility should be incorporated into future models. This will allow for live streaming to hand-held devices, and will drastically alter the user experience from the point of view of the coaches involved in the sport. Examination of Speed Coaches from a Human Factors perspective provided the largest number of potential improvements, as this was the section that focused on rowers opinions and desires. As this is a product that is not strictly necessary in order to row competitively, suggestions that allow for an improved user experience were considered highly important. It was determined that designing and distributing a new Speed Coach model would be expected to take approximately one year.

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1 Introduction

Speed Coaches were described, and the scope and method of the analysis were outlined. 1

2 Recommendations

The result of conducting the analysis was a list of 10 recommendations. 1

3 Qualitative Analysis

The survey conducted for this report was introduced and analysed. The relevant results were displayed and the most important user opinions were stated. It was found that the majority of rowers use Speed Coaches, and that the most popular brand of Speed Coach is Nielson-Kellerman. Potential sources of error were also examined. 2

4 Quantitative Analysis

The population size of the Canberra Rowing Community was estimated to be 1782 ± 427 . The confidence interval of the survey results was calculated to be $\pm 13.18\%$. 4

5 Human Factors

The following recommendations were made: Speed Coaches should: employ touch screen technology to improve the user interface, include a 3-Axis Accelerometer in order to measure power curves, incorporate wireless internet compatibility to allow live data transfer to hand-held devices, display information regarding rower improvements in order to motivate the user, pair with a motion sensor in order to avoid collisions. 5

6 Time Factors

It was recommended that Speed Coaches should be powered by two CR2032 batteries to minimize user time spent maintaining the energy source. The expected time frame of designing and distributing a new Speed Coach model was researched and found to be approximately 1 year. 7

7 Material Factors

It was recommended that a Design of Experiments Analysis be undertaken to determine a new material for the casing of the Speed Coach that would protect the device and allow it to float. A Material Audit and End-of-Life Analysis were also undertaken in order to understand the material impacts of current Speed Coach models. 9

8 Energy Factors

It was recommended that Speed Coaches include a 3-Axis Accelerometer along with compatibility with an impeller in order to minimise idle time before the device automatically switches off. It was also recommended that a photovoltaic strip be included in the top of the Speed Coach case to improve energy efficiency. 10

9 Dynamics and Control Factors

It was recommended that a piezoelectric sensor be paired with Speed Coaches in order to allow for more accurate 'stroke rate' measurements. The delay in data display was also investigated leading to the conclusion that current delays are acceptable. 12

10 Cost Factors

The overall life-cycle cost of the system was investigated. A cost-benefit analysis were conducted of using both an impeller and an accelerometer to measure speed, and of utilizing a piezoelectric sensor to measure 'stroke rate.' This analysis concluded that these recommendations were beneficial for the system. The expected pay-back period of

incorporating a photovoltaic strip into the Speed Coach case was found to be approximately 2 months for an average rower. **13**

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1 Introduction

This portfolio aimed to analyse the current models of Speed Coaches that are available for use by rowers world wide. The dominant Speed Coach brand throughout the rowing world is Nielson-Kellerman, and it was their Speed Coaches that were the basis for analysis. An example of a current Speed Coach model available to rowers is the SpeedCoach Gold, which is referenced throughout this portfolio. This model, along with an image illustrating how a Speed Coach is set up within a boat are shown below. Rowers use Speed Coaches to obtain live updates of their movements, through features such as ‘stroke rate’ (measured in number of strokes per minute), and ‘speed’ (measured in time taken to complete 500m at the current boat speed). Rowers use this data to adjust their movements both in training and races, and also to plan training sessions and monitor their long term performance. While current Speed Coach designs are considered very useful by rowers, there are also many areas of the design that are considered to be areas of potential improvement (see **Appendix 3 & 4**).



Figure 1: SpeedCoach Gold (*NK Australia, 2015a*)

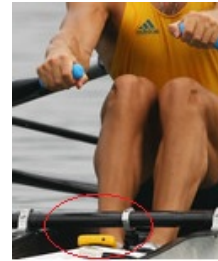


Figure 2: How A Speed Coach (circled) is Set Up (*Dinares, C, 2015*)

This portfolio took a systems engineering approach to analyse the Speed Coach system from a variety of analytical angles. The scope of the analysis was limited to the Speed Coach device itself, and the accessories that it requires to function. Current statistics and views on Speed Coaches were collated through both qualitative and quantitative methods, before the system was examined from human, time, material, energy, dynamics and control, and cost perspectives. From these perspectives it was possible to isolate areas of current Speed Coach design that could be improved, leading to the list of recommendations outlined below.

2 Recommendations

It was concluded that future Speed Coach models should include the following:

1. Touch screen technology.
2. A 3-Axis Accelerometer, to allow for power curves to be measured and displayed.
3. Wireless internet compatibility allowing for live streaming of data to a hand-held device from multiple Speed Coaches simultaneously.
4. Updated software to allow the device to indicate to the rower that they have just achieved a new personal best for a certain criteria.
5. A motion sensor attached to the bow of the boat, to be used to warn the rower of an imminent collision.
6. Two CR2032 batteries, in order to minimise user time spent maintaining the battery life.
7. A new material with which to construct the casing, to be selected through a DoE analysis in order to optimize both protection and floatation. Carbon Fibre was used as a suggested possible choice.
8. Compatibility with both an accelerometer and an impeller for ‘speed’ measurement.
9. A photovoltaic strip in the top section of the Speed Coach case, to improve energy efficiency.
10. A piezoelectric sensor located on the rigger, to be used to measure ‘stroke rate’.

3 Qualitative Analysis

In order to gain an understanding of how rowers currently use and view Speed Coaches, a survey was created (**Appendix 1**). This survey was aimed at both rowers and their coaches, as these are the two groups that benefit from the data that Speed Coaches provide. The survey was distributed predominantly to rowers in the Canberra area, via Facebook and the ACT Rowing website (*Rowing ACT, 2015a*), with a small overseas sample (a member of Canberra Rowing Club sent the survey to the Irish National Rowing Team, several of whom also completed the survey). An assumption was made that this was a valid sub-population of the wider rowing community, an assumption that was made for the following reasons.

Rowers in Canberra, like all rowers, use Speed Coaches in order to gain the most benefit out of their training programs, and also to receive live updates of their movements throughout a race. Furthermore the most popular brand of Speed Coach in Canberra is Nielson-Kellerman, which is also consistent with the wider rowing community. These statements were validated in **Section 3.2** by the survey results and with an interview conducted with a current member of the Australian Rowing Team.

The survey aimed to gain information in the following areas: 1. The value rowers put on their Speed Coach compared to the experience of the rower. 2. The proportion of rowers who use Speed Coaches compared to age and level of experience. 3. The main features that rowers and coaches value in the Speed Coach. 4. The brands of Speed Coach that rowers used. 5. Areas that rowers and coaches feel that current Speed Coach models could be improved.

3.1 Survey Results:

In order to analyse the results of the survey, a Python script was created, in order to tally and code the responses quickly and repeatedly as more responses were submitted. The final output of this code is included as **Appendix 2**.

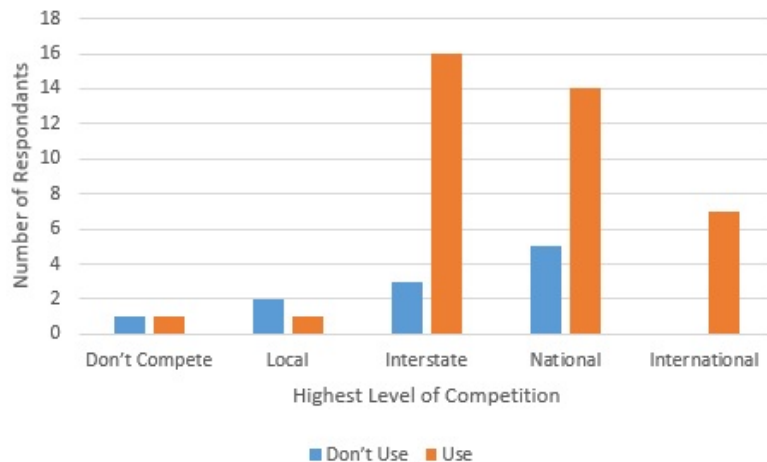
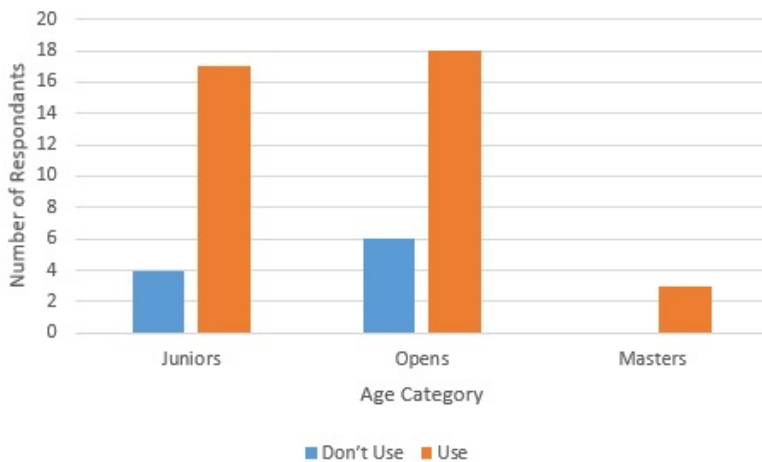


Figure 3: Rowers Age V Use of Speed Coach

Figure 4: Level of Competition V Use of Speed Coach

Figure 5 results were collated by ranking the multiple-choice responses of Question 7 of the survey, then tallying and averaging the results.

3.2 Discussion of Results

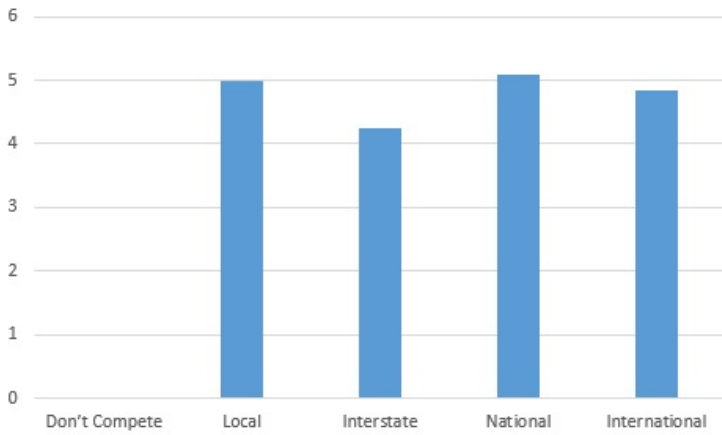


Figure 5: Value Placed on Speed Coach Use by Rowers (0 = no value, 7 = maximum value)

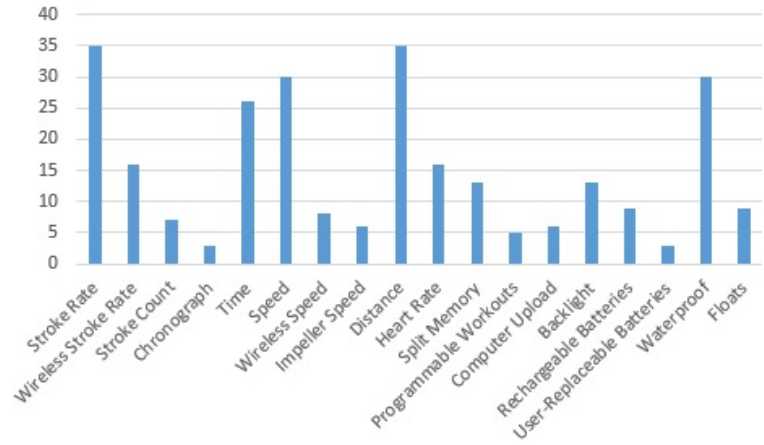


Figure 6: Value Placed on Current Speed Coach Features

The survey indicated that the majority of rowers use Speed Coaches, with those who compete more seriously tending to use them in greater numbers (it is difficult to be completely certain of this second point given the low number of respondents who identified themselves in the lower competition categories, however it is noteworthy that not a single international rower indicated that they didn't use a Speed Coach). When rowers did not use Speed Coaches, the reasons for this were varied, with the one consistent theme being that the devices are currently too expensive. Many of the respondents provided feedback regarding areas of the Speed Coach design that they believed could be improved. The most common of these were that the length of the battery life is too short, the device is too large, and it should be able to float. A response by several coaches was that live feedback between the Speed Coach in the boat, and the coach is currently difficult. A full list of suggested improvements is included as **Appendix 3**. These suggestions provided a starting point for the analysis undertaken throughout this report.

The respondents also indicated how they thought their Speed Coach had been most helpful for their performance. Again a full list of these responses is included as **Appendix 4**. The most common points in this section were that the Speed Coach allowed the rower to better control their speed, and track their performance over time.

These responses were used as a basis for further analysis of the Speed Coach from different analytical approaches, as they were very helpful for identifying current strengths and weaknesses of Speed Coach designs.

The preceding statements were validated by a 'coding' process, whereby 'Ctrl-F' was used to count the number of certain key words such as 'battery', and results were also scanned by eye to pick up similar phrases, for example; 'smaller', 'thinner' and 'lighter', in relation to the size of current models (*Saldana, 2015*).

The assumptions stated above regarding the Canberra sub-population were validated by the respondents of the Irish Rowing Team, all of whom indicated that they used Nielson-Kellerman Speed Coaches, and provided similar responses in other areas (it was possible to determine which responses were theirs as it was indicated by a fellow rower when these individuals were filling out the survey, so the timestamps could be used to identify them). Furthermore, a current member of the Australian Rowing Team stated that "everyone uses NK [Nielson-Kellerman], they have the market stitched up" (*Mr. T Perry 2015, pers. comm., 18 Sep*) when asked if any brand difference was evident in overseas competition. A full transcript of this interview is included as **Appendix 5**.

3.3 Sources of Error

The interview and analysis of survey responses were conducted in an attempt to rule out Sampling Error, which could have arisen if the assumptions discussed above were invalid, leading to potentially inaccurate statements being made about the wider rowing community. However Sampling Error was still possible due to the small

sample size (54 respondents). In order to further analyse the possibility of Sampling Error, the confidence interval of the results is examined in **Section 4.2**. Other potential sources of error in this survey included Coverage Error, which was a concern due to the survey being circulated mainly among friends and family. This resulted in there being a disproportionate number of respondents in the lower age demographics, whereas other age groups were less well represented. In order to minimise this source of error, the survey was uploaded to the ACT Rowing website, as mentioned above. However, there remained a clear under-representation of Masters rowers (aged 35+), resulting in care being required when drawing conclusions regarding this demographic. Conducting a simple survey, with a majority of answers required in the form of multiple choice was done as a method of minimizing Response Error. This approach appeared to be successful, as all survey results seemed reasonable and showed an understanding of the questions and the answers that were required. In order to avoid Interviewer Error, the interviewee was not prompted with the brand name ‘Nielson-Kellerman,’ so as to avoid hinting at the expected answer. Finally, Processing Error was avoided by writing a Python script to process the results, negating the potential for human error when tallying the responses (*Statistical Language, 2015*).

4 Quantitative Analysis

In order to determine how reliable the results of the survey were in gauging peoples use and opinions of Speed Coaches, the confidence interval of the results was calculated. Before this was done the Canberra rowing community needed to be estimated.

4.1 Canberra Rowing Community Estimation

The Rowing ACT website provides a list of all the community clubs and educational institutions that have a rowing presence in the ACT (*Rowing ACT, 2015b*). This list contains 4 community clubs, and 7 educational institutions. Of these 11 rowing clubs, it was possible to find member information of 3 of them. It was found that The Australian National University Boat Club (ANUBC) had 138 members in 2012 (*ANUBC, 2012*), that Black Mountain Rowing Club (BMRC) had 110 members in 2010 (*McMahon, V, 2011*), Canberra Rowing Club (CRC) currently has 238 members according to their boat captain (*Mr. T. Trobe 2015, pers. comm., 18 Aug*). As there was no further information available, the average number of members of these 3 clubs (162) was used to estimate the total Canberra Rowing population.

On average it is expected that these sample club sizes miss the overall mean by one standard deviation. Therefore the standard error of estimation of the mean could be calculated using σ/\sqrt{n} , where σ is the standard deviation of the sample club populations ($\sigma = 67.3$), and n is the number of samples ($n = 3$) (*Western Michigan University 2015*), (*TEDEd, 2015*). Therefore the average number of members in each club is: $162 \pm 67.3/\sqrt{3} = 162 \pm 38.6$. By multiplying by the number of clubs, the total size of the Canberra Rowing Community could be approximated: 1782 ± 427 .

4.2 Confidence Interval of Survey Results

Using the equations below, the confidence interval could be attained for the given number of respondents (*Creative Research Systems, 2015*).

$$c = \sqrt{\frac{Z^2 p(p-1)}{SS}} \quad (1)$$

Where: SS = sample size, Z = Z- score (assumed to be 1.96), p = percentage who picked certain choice (assumed to be 0.5 to ensure that the confidence interval was correct regardless of the percentage), and c = the confidence interval.

Equation (1) can be corrected for a finite sample using:

$$SS' = \frac{SS}{1 + \frac{SS-1}{pop}} \quad (2)$$

Where: *pop* is the population, *SS* is the original sample size, and *SS'* is the corrected sample size to be used in Equation (1).

Taking the population size to be 2209 (upper bound for conservative estimation), the number of respondents to be 54, and a confidence level of 95% ($Z = 1.96$), the confidence interval was calculated and found to be 13.18%. It was thus possible to state with 95% certainty that the figures displayed above are an accurate representation of the trends in the Canberra rowing community to within a confidence interval of $\pm 13.18\%$. Given the assumptions stated above, these results are expected to be indicative of the wider rowing community, within the same confidence interval.

5 Human Factors

The results of the survey articulated many human-related issues that required analysis. The most common and relevant of these suggestions related to the following three categories:

Display: It should be possible to view more features on the screen at one time, and easier to view the display on the screen from all points of the rowing stroke. The display should also be touch screen compatible.

Functions: The device should be able to show you the power curve throughout each stroke. The device should also pick up changes in rate and speed faster than it currently does.

Device Interaction: It should be easier for an external individual (such as a coach or training partner) to view the live display of the Speed Coach. It should also be easier to upload the data to another device or to the internet post session.

These suggestions all relate to the user experience, and therefore came under the banner of ‘Human Comfort.’ This was one of the two issues approached in this section, the other being ‘Human Safety.’

5.1 Human Comfort

Display: The screen in current Nielson-Kellerman Speed Coaches comprises of a liquid crystal display, with an electro-luminescent backlight that illuminates when an in-built phototransistor senses that the device is being used in low light conditions (*NK Australia, 2015a*). However, despite the company claiming that contrast is maintained in all conditions (*NK Australia, 2015a*), several survey respondents maintained that it was hard to view the display when they were at the catch (front of the stroke), and at the finish (the end of the stroke). However, there are no features that can be viewed on the Speed Coach display that require viewing more than once per stroke. Furthermore, certain features such as speed and stroke rate are only updated once per stroke (*NK Australia, 2015a*) rendering more frequent viewing of the device redundant. For these reasons it was deemed not necessary to pursue this anthropometric issue. Several respondents mentioned that a touch screen would make the device more user friendly, and it is the 1st recommendation of this report that future Speed Coaches do incorporate this technology.

The features that are displayed on the screen of the device are controlled by pressing the single button on top of the device. As such, there is minimal scope to change the features that are displayed on the screen, with only three pre-set combinations of features possible to choose from. Touch screen compatibility would allow the user to potentially drag features that they wish to view into the area of the screen, allowing them to create a display

that is most pleasing to them. Alternatively this could be done with computer software, with a preset screen created by the user on their computer, and then uploaded to the device to be used at the individuals whim.

Features: Many respondents mentioned that they would appreciate being able to view a ‘force curve’ illustrating how they apply force throughout the stroke. This feature is available on static rowing machines (Figure 7), and also on a Speed Coach app that is available on smart phones (*RowPerfect, 2015*).



Figure 7: Force Curve Shown on the screen of a Concept 2 Rowing Machine (*Concept 2, 2015*)

The feature on the app; ‘Rowperfect’ works by accessing the smart phones accelerometer, and monitoring the surge of the boat during the stroke. It would therefore be possible to append this feature to standard Speed Coach models, so long as the device had an inbuilt accelerometer. As not all current Nielson-Kellerman Speed Coaches have inbuilt accelerometers, this feature would only be possible in certain current models. However, as accelerometers are relatively cheap (*SparkFun Electronics, 2015a,b*) it is the 2nd recommendation of this report that accelerometers are incorporated into all future Speed Coach designs. Further reasons for this recommendation are discussed in Section 9.

Device Interaction: A common complaint, especially among the coaches who answered the survey was that current Speed Coach designs do not offer very convenient methods by which a coach can get a live feed of the data that a rowers Speed Coach is collecting. For this to be achieved currently, two SpeedCoach XLs must be bought at a cost of \$759 each. These Speed Coach models incorporate a digital spread spectrum transceiver which is able to send data in real time at a range of up to 400m (*NK Australia, 2015b*). However, for this transfer to be completed, one Speed Coach must be in the rowers boat, while the other is in the coaches possession. In this scenario all the other featus that these Speed Coaches are capable of are wasted, as the coach is simply using their device to receive data. Furthermore, even with this large financial investment, the coach is only able to view the data of one Speed Coach at a time. If they wish to view more than one they have to unpair and then re-pair, making any sort of real time comparison between crews impossible. A sensible solution would be to program a Speed Coach to be able to send data via the internet to a hand-held device such as an iPad, that the coach could use to monitor multiple crews at the same time. Such a concept has recently become the focus of a start up company based in Canberra called Coachlive (*CoachLive, 2015*). This company sent a survey to members of several Canberra based rowing clubs, asking if they thought their club would be interesting in a device that was capable of this sort of live interaction. The results were very positive (*Mr. T. Watkins 2015, pers. comm., 7 Aug*), and they are currently in the early stages of trialling their software. The 3rd recommendation of this report is that future Speed Coaches incorporate this concept into their designs.

A second point raised by survey respondents related to the update speed of the device. This is a dynamics issue, and will be discussed in Section 9.

A final recommendation based on **Human Comfort** relates to positive reinforcement. Rowing is a physically demanding sport, and rowers and coaches will look at the data supplied to them by the Speed Coaches to determine whether their hard work is translating into improvements. In order to maximise user satisfaction it is

critical that this device is capable of clearly indicating such improvements when they occur. Some examples of how this could be done include animations to show the rower that they have set a new personal best for a certain distance, or that they have just broken their previous fastest boat speed. Rewards for improvement such as these are sure to significantly enhance the user experience and satisfaction. It is the 4th recommendation of this report that Speed Coach software be updated to include reinforcement of this nature.

5.2 Human Safety

While there are no risks associated with using a Speed Coach, there is potential for a Speed Coach to be employed to help increase rower safety. Rowing is an unusual sport in the sense that you do not face in the direction that you are going. As such, accidents involving a rower colliding with another rower or some other obstacle are quite common, and often cause thousands of dollars worth of equipment damage, as well as potentially serious injury. While the Speed Coach could not prevent these incidences from occurring directly, it could be paired with some other monitoring device that could be used to alert the rower of an impending collision. A motion sensor attached to the bow of the boat, and wirelessly connected to the Speed Coach was deemed to be the most logical pairing to avoid collision. There are cheap motion sensors with wi-fi connectivity, such as the mydlinkTM (*D-Link UK, 2015*) that could be utilised for this purpose. Due to the difference in price between a motion sensor and boat repairs, which can be thousands of dollars, no further analysis from a cost perspective was deemed necessary. The benefit of such a pairing makes clear financial sense.

The motion sensor would need to send a signal to the Speed Coach, so that the rower could be audibly or visually alerted to an impending collision. However, without proper set-up this alert would be triggered at the start and end of each session, when the boat parks at a jetty, or if a coach boat moves too close while talking to a crew. A solution to this dilemma is to only send out the alert if the boat speed (as measured by the accelerometer) is above a certain value, deemed too high for the boat to be parking or safely near another boat. With this addition, this suggestion would be a potential way to improve rower safety, and is thus the 5th recommendation of this report.

6 Time Factors

As the scope of this report is confined to the Speed Coach itself, there were limited opportunities to analyse it from a time perspective. From the perspective of the user there is nothing that will vary with time, and nothing that will be time exhaustive. The user is only required to place the Speed Coach in the boat, and turn it on, then do the same in reverse at the end of the session. From the perspective of the system itself, the battery capacity was examined, as there is a time dependent aspect that is noteworthy. Finally, as this report aims to provide recommendations for a new Speed Coach design, the conception and implementation process was examined, in order to estimate a time-frame for such an undertaking.

6.1 Battery Capacity

Many respondents of the survey mentioned that they believed that the battery life of current Speed Coach models could be improved. In this section, the battery capacity of current Speed Coach models was examined from the perspective of their implications on time, while the battery capacity was also examined from an energy efficiency perspective in Section 8.

Nielson-Kellerman has 3 main Speed Coach models available, each with its own battery set up. The SpeedCoach Gold contains two CR2032 batteries, one for the display and one for the backlight. These batteries are user-replaceable, and have a life expectancy of 600 hours for the display battery, and 20 hours for the backlight battery

(*NK Australia, 2015c*). The SpeedCoach GPS has a single Lithium-Poly battery that is user-rechargeable, but not user-replaceable. This battery provides approximately 8 hours of battery life (backlight dependent), and has an expected life of 300 cycles at full capacity, before the capacity is reduced to 80% of original (*NK Australia, 2015d*). The SpeedCoach XL3 has a single Lithium ion battery that is user-rechargeable and user-replaceable. The battery has 72 hours of use per charge (25 with constant backlight, 8 with radio use), and charges in under 3 hours (*NK Australia, 2015e*). Of these three configurations, the configuration of the SpeedCoach Gold is optimal from the perspective of the time the user spends maintaining the battery life. It was therefore necessary to determine the expected life time of this configuration.

A typical rower goes for an average of 3-5 one hour rows per week, while an elite rower will go for perhaps 7-10 rows of the same length per week (*AIS, 2015*). Based on the assumption that an average rower rows 4 hours per week and an elite rower rows 8 hours per week, and using data from Nielson-Kellerman, it was then possible to equate this to the length of the battery life, as illustrated in Figure 8.

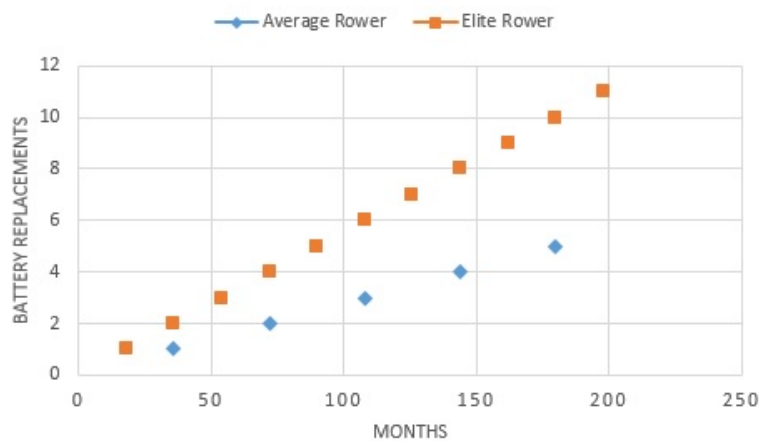


Figure 8: BoT Graph of SpeedCoach Gold Battery Life

This Figure indicates that battery replacement is only required at most every one and a half years. A similar BoT analysis was done of the backlight battery, and it was found that this battery would require replacing once per year (assuming 10% of each session was undertaken with the backlight on). Given these values, the time taken to replace the battery would be less than the combined time of recharging the battery every 8 or 72 hours of use, which would be required for the other battery configurations. It can also be seen that the energy consumption of the backlight is an example of the Pareto Principle, as it requires a separate battery just to fulfill the requirement of this single feature. However, without this feature, rowers may find their Speed Coach useless for large sections of their training time, especially in the Winter months. For this reason it was concluded that the second battery was a necessary requirement, despite the trade off with energy consumption. It is therefore the 6th recommendation of this report that future Speed Coach designs incorporate two CR2032 batteries, in order to minimise user time spent maintaining the battery life.

6.2 Design Implementation Time Frame

In order to determine how long it would take to design and distribute a new model of Speed Coach, CoachLive (mentioned previously) were contacted, as they are currently aiming to do just that. Coachlive responded with a Gantt Chart of their expected progression through the design and prototyping phases, which correspond to their aim of releasing their system to the public in time for the Summer rowing season of 2016, approximately one year

from the creation of their company (*Mr. T Watkins 2015, pers. comm., 14 Aug*).

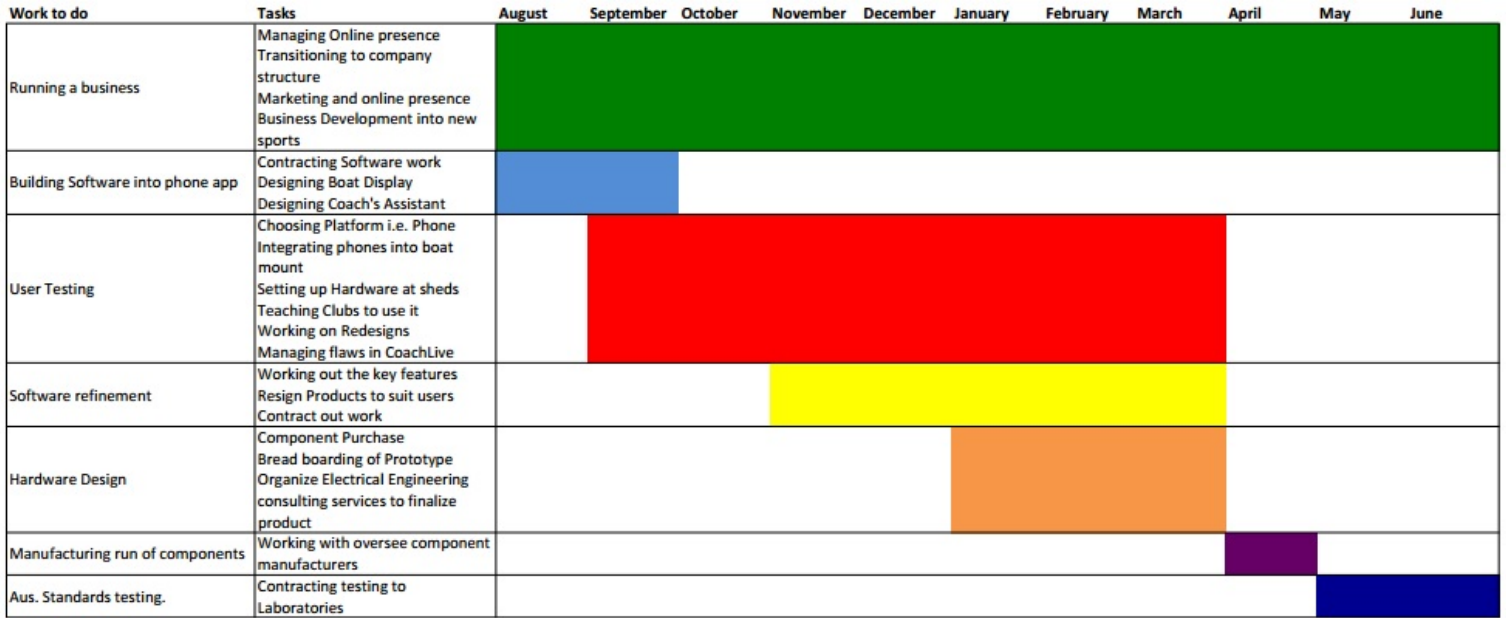


Figure 9: Gantt Chart provided by local business CoachLive (*Mr. T Watkins 2015, pers. comm., 14 Aug*)

As this report is also examining the implementation time of a new model of Speed Coach it is expected that this implementation would require a similar time frame (1 year).

7 Material Factors

This system is isolated from the point of view of material use and material flows. However, there are material aspects that required examination. A Speed Coach must be both waterproof and able to float (incredibly, only the most expensive of current models of Speed Coach do currently float), as these were two features that were rated highly by survey respondents (see Figure 6 and **Appendix 3**). Therefore the design required optimization to fulfill these requirements. A Material Audit and an examination of the Speed Coaches end-of-life were also conducted in order to understand the material impacts of current Speed Coach models.

7.1 A waterproof design that also floats (Outline of Potential DoE Analysis)

Nielson-Kellerman states that they “strive to make all its rowing products float”, however, in the case of one example (the SpeedCoach Gold), they go on to state “however, the combination of the backlight, the extra battery, and the bumper all add up to a product that goes down and stays down” (*NK Australia. 2015c*). In order to address this, the weight and dimensions of Speed Coaches that do and do not float were examined, in order to determine an optimal combination of materials that would allow these requirements to be met.

SpeedCoach	Dimensions (m^3)	Weight (W)	Buoyancy Force (F)	F-W
SpeedCoach XL3	$0.1143 \times 0.0762 \times 0.0381$	2.47N	3.25N	> 0: Floats
SpeedCoach Gold	$0.056 \times 0.083 \times 0.021$	1.16N	0.96N	< 0: Sinks

Table 1: Buoyancy Force Comparison of Current SpeedCoach Models (*NK Australia, 2015b*)

As stated above, the reason that the SpeedCoach Gold does not float is because it requires the protective bumper, and the extra battery for the backlight. However, if the material that made up the case of the Speed Coach were altered from injection-molded polymer to something stronger, yet lighter (such as carbon fibre), the device would not require that protective bumper, and would be lightweight enough to float. An alternative option was

to increase the volume of the protective bumper until the volume of the device is large enough that it floats regardless. However, several survey respondents voiced the wish that Speed Coaches be either smaller, lighter or thinner, and as the first suggestion improves all three of these aspects, as well as fulfills the important criteria that it floats, this was the suggestion that was deemed more appropriate. Therefore it is the 7th recommendation of this report that a Design of Experiments analysis be undertaken that considers the variables ‘floats’, ‘lightweight’, ‘small’, ‘thin’, ‘strong material’, and ‘waterproof’, in order to find the optimal material, and optimal volume of that material that best satisfies these parameters, and thus is best suited for use as the casing of the Speed Coach.

7.2 Material Audit

A Material Audit of the SpeedCoach Gold was done as a reasonable estimation of the typical embodied energy of current Speed Coaches models.

Material	Weight (g)	Embodied Energy (MJ/kg)	Total Embodied Energy (MJ)
LCD Display	5	12.7 (<i>Australian Government, 2013</i>)	0.0635
Rubber Case	20	110 (<i>Australian Government, 2013</i>)	2.2
Injection-Molded Polymer Case	30	90 (<i>Australian Government, 2013</i>)	2.7
2× BAT CR2032 (Lithium Battery)	2×3.2 (<i>TME, 2015</i>)	-	$2 \times 2.376(10^{-4})^*$
Internal Wiring	56	$\geq 1008^{**}$	≥ 56.5
Total	118		$\geq 114\text{MJ}$

Table 2: Material Audit of SpeedCoach Gold (measurements done using kitchen scales where possible)

* *In order to calculate the embodied energy of the battery, the capacity of the battery (220mAh) was multiplied by the voltage (3V), and divided by 1000 to get a value of 0.66Wh (TME, 2015). This was then converted to MJ to find the energy output over the batteries lifetime. Lithium batteries have an ESOI value of 10 (Stanford University, 2015), meaning that the energy output divided by 10 would give the embodied energy, which is given in Table 2.*

***It is very difficult to get embodied energy for any sort of electrical wiring. However, it was stated in Lowtech Magazine that manufacturing one kilogram of electronics requires between 280kWh and 28MWh of electricity (LOW-TECH MAGAZINE, 2015). The lower limit was used in Table 2 in order to give a best case scenario of the embodied energy of the internal wiring.*

7.3 End-of-Life

As the largest component of this system is the internal wiring, recycling does not provide an effective means of reducing the energy required by the system. This is due to the energy requirements of the initial extraction and processing of the materials being substantially larger than the energy requirements of the manufacturing process (*LOW-TECH MAGAZINE, 2015*). Speed Coaches are therefore an example of cradle-to-grave technology. However, enabling internet connection, as was recommended previously in this report will allow for the systems software to be updated as required, without the need for a new device. A single device is thus expected to last the entire career of the individual who possesses it, reducing the end-of-life impact as much as possible.

8 Energy Factors

Assuming that Recommendation 6 is enacted, the entire power supply of this system will be provided by two CR2032 lithium batteries. It was also stated in Section 6 that it was expected that these batteries would require

replacing once every 1.5 years and 1 year respectively. While this current battery life is reasonable, there is room for further improvement. Two methods of increasing energy efficiency were examined in this section; reducing inactivity time before the device automatically powers off, and the implementation of a solar power component.

8.1 Reducing Time Taken to Power-off when Inactive

Examining current models of Speed Coach it was found that there were two different time periods that were required before the device would turn off if unused. The SpeedCoach GPS requires 8 minutes of inactivity (*NK Australia. 2015d*), while the Speed Coach XL3 requires 17 minutes (*NK Australia. 2015e*). Inactivity in this context means no buttons being pushed and no movement. However, while out rowing, it is almost impossible for the boat to be completely stationary, as any wind or wave activity leads to small movement. It would therefore seem reasonable to reduce this time duration, if it could be ensured that the sensors in the device were sensitive enough to pick up these small changes of movement. This would ensure that the device would be able to sense when it was no longer being used on the water. Movement sensors in Speed Coaches currently come in two categories; impeller, or 3-axis accelerometer. As 3-axis accelerometers are only expected to provide $\pm 0.5m/s^2$ accuracy (*Vernier Software & Technology, 2015*), it would be difficult for devices with this technology to pick up such small movements, and it is unlikely that improvements will be possible. However, devices with impeller technology are capable of much more sensitive results (expected accuracy of 98% (*NK Australia. 2015f*)), and here improvement is certainly possible. Therefore the 8th recommendation of this report is to allow Speed Coaches to be capable of both 3-axis accelerometer and Impeller motion measurement, and to also program them to reduce inactivity time if an impeller is available to be used. A cost-benefit analysis of including both impeller and 3-axis accelerometer technology in the design is located in Section 10.

8.2 Solar Power

As rowing is undertaken entirely outdoors, with the device always orientated in the same direction, there is the potential for the device casing to at least partly comprise of a photovoltaic material. A design alteration of this kind would undoubtedly improve the battery life of the system, but would have other, negative impacts that require analysis. The most prominent of these issues would be an increase in cost due to the relative price of photovoltaic materials compared to material of the outer case (which is currently the rubber bumper, but will be a material such as carbon fibre if Recommendation 7 is enacted). The embodied energy of the system would also change from either 1.1MJ (rubber) (or 236MJ/kg for CFRP (*US Department of Energy, 2013*)) to include a thin strip of photovoltaic materials which would have an average embodied energy of 1305MJ/m² (*Circular Ecology, 2015*). However, as the surface area over which the photovoltaic strip could be placed is small, the embodied energy is expected to change by a negligible amount.

Using the following equation for photovoltaic efficiency, and estimating the necessary parameters the following value for ‘power generated’ could be established.

$$P_m = \eta(G \times A_c) \quad (3)$$

Where: η is the energy conversion efficiency, P_m is the maximum power point, G is the irradiance, A_c is the surface area of the material.

Using Equation (3), and $\eta = 0.2$ (Average solar cell efficiency (*Green, M, et all, 2014*)), $G = 342W/m^2$ (Average on Earth (*Dargan, M, 2014*)) , $A_c = 0.021 \times 0.083$ (top surface of the SpeedCoach Gold), the expected

power output (P_m) of the photovoltaic strip was found to be 0.12W. Given this value, a pay-back period analysis could be conducted to determine the period of time required to be reimbursed the cost of making this addition to the Speed Coach case. This analysis was undertaken in Section 10, where it was concluded that this was a valid suggestion, and that the photovoltaic strip should be utilized to supplement the energy supply to the backlight, as shown in Figure 10. This suggestion was listed as Recommendation 9 of this report.

8.3 Sankey Diagram

A Sankey Diagram was constructed in order to illustrate the energy flow through the system, and how Recommendation 9 would be incorporated (*BBC, 2015*), (*Google Developers, 2015*).

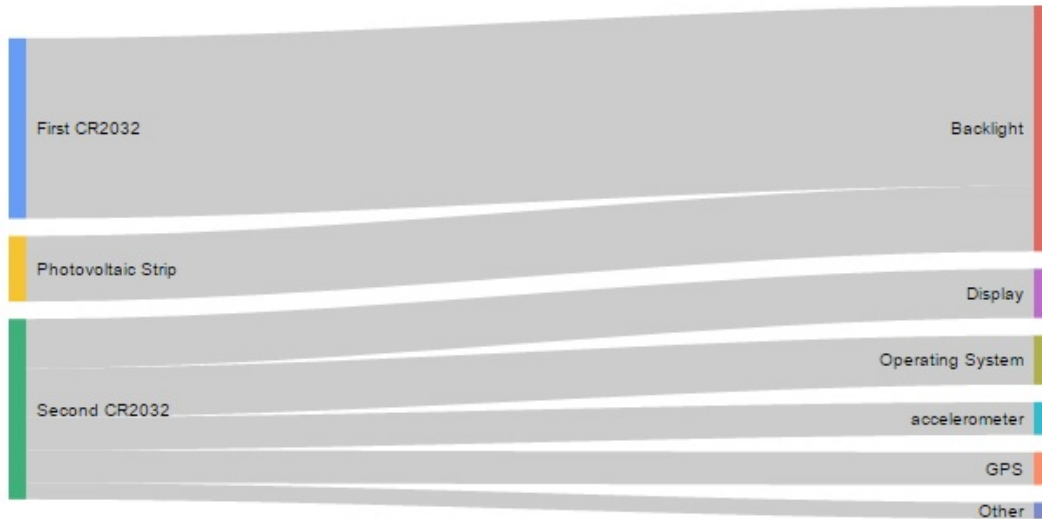


Figure 10: Sankey Diagram of Energy Flow Including Recommendation 9 (not included in current designs)

9 Dynamics and Control Factors

The system described in this report is inherently feedback orientated in its purpose. The system is a live aid to rowers who wish to track their performance, and as such it must respond to the information provided by either the impeller, accelerometer or GPS and display this information to the user in real-time. The user can then adjust their performance accordingly and have their change verified by the feedback cycle. This cycle is an example of a feedback structure in which the rower has control, as they are triggered to vary their performance based on the sensing mechanism. The coach can also be a controlling factor if they also have access to the Speed Coach data, as they can vary their instructions based on information. (*Murray, R, 2009*)

9.1 Feedback Structures

In this feedback cycle, it would seem that faster, more continuous feedback is optimal in allowing the individual to gain the most benefit from its use. However this is the case for some of the information provided by the system, but for other data it is true only to an upper limit. For example, two of the variables that the system monitors are ‘distance travelled’ and ‘boat speed.’ If the user is taking part in a race, it is certainly best if they are provided with continuous and instantaneous feedback regarding how far they have travelled, and how far they have to go. Delays in such information could lead a rower not carrying out their race plan effectively, for example, they might start their final sprint for the line too late. Conversely however, instantaneous ‘boat speed’ data would be confusing and potentially unhelpful, as ‘boat speed’ varies dramatically between each stroke. If the rower is provided with speed data at all points between each stroke, the onus would be on the rower to keep track of the maximum speed displayed each stroke and ignore the rest of the data in order to

determine if they are changing speed. Otherwise they would have to somehow average the speed over the course of a stroke in order to determine their overall boat speed. Both these scenarios are much less helpful than if the system simply provided the user with boat speed data taken at a consistent point during a stroke. Nielson-Kellerman Speed Coaches currently operate by averaging the speed over the stroke, and updating the display every stroke (*NK Australia, 2015g*). It does appear that this delay (1 update per stroke) is the optimal way to display speed data to the user, and as such there are no suggested improvements for this aspect of the feedback system.

Another feature provided by Speed Coaches that was deemed important by survey respondents was the stroke rate (strokes per minute). This feature allows the user to control their speed with more ease than ‘boat speed’ data. If the ‘boat speed’ is indicating that the rower is slowing down, there may be any number of reasons why this might occur, for example, variations in wind or waves. However, if the rowers stroke rate drops, that is an immediate and concrete indication that the rower is performing at a lower intensity that they were previously. Feedback of the stroke rate to the user is done either via a maget located on the boat below the seat that senses the seat moving over the top of it, or via a 3-axis accelerometer in more recent editons (*NK Australia, 2015g*). Neither of these methods is ideal, and both can produce inaccurate results under different circumstances.

For systems that utilise the magnet approach, it has been found that slight variations in the speed at which the rower moves between each stroke can lead to unrealistic stroke rate data [27](*NK Australia, 2015*). This problem is a more regular occurance in larger boats of up to 8 rowers, in which there is still only 1 magnet. This means that slight variations in the lead rowers movement has an even more unrealistic influence, as one rower is not necessarily representative of the crew. In a study conducted by Nielson-Kellerman, a crew of 8 rowers was asked to row at 26 strokes per minute for 5 minutes using both the seat magnet and the accelerometer displayed on seperate Speed Coaches side-by-side. It was found that the Speed Coach utilising the maget indicated a stroke rate of between 24.5 and 27.5 strokes per minute, while the Speed Coach utilising the accelerometer indicated a stroke rate of between 25.5 and 26.5 strokes per minute (*NK Australia, 2015h*).

While the accelerometer proved more precise measurements in this experiment, there are circumstances that lead to a decrease in accuracy. Nielson-Kellerman has indicated that these circumstances include: when the rower is passing by power lines, bridges or other sources of electromagnetic radiation. Furthermore, the accuracy also decreases when the rower is rowing at 15 strokes per minute or less (*NK Australia, 2015h*).

A suggestion of how to improve upon these current methods of gathering stroke rata data would be to have a device such as a motion sensor or a piezoelectric sensor attached to the boats rigging, at the point where the oar is attached. This device could then monitor the actual stroke arc and determine when the oar changes direction. As the stroke would be measured directly, slight variations in the rowers movement between strokes would not matter, thus creating a stable feedback structure. This device could then communicate with the main Speed Coach unit via wifi or bluetooth. Given the issue discussed previously of motion sensors potentially picking up unwanted movement at times such as parking the boat, it is the 10th recommendation of this report that a piezoelectric sensor be used for this role.

10 Cost Factors

In this section the overall life-cycle cost of current Speed Coach models was investigated. (*Australian Government, 2015*) Cost-benefit analysis of the use of both impeller and accelerometer technology was investigated, as was the use of a piezoelectric sensor to measure stroke rate. Finally the pay-back period of the addition of a photovoltaic strip to the Speed Coach case was analysed.

10.1 Life-Cycle Costing

Upon investigating the cost of current Speed Coach models it was found that all costs were aquisitional costs, apart from the ongoing cost of replacing the batteries.

Acquisition	Speed Coach Cost	\$199 - \$619
	Impeller Cost (optional)	\$49
	Carry Case (optional)	\$10
	Protective Case (optional)	\$10
	Seat Magnet (optional)	\$10
	Speed Coach Mount	\$15
Maintenance	Battery Replacement	\$5/1.5 years + \$5/year

Table 3: Life-Cycle Cost (all data was acquired from (*NK Australia, 2015i*))

It is evident that the largest factor contributing to the cost of the system is the cost of the particular Speed Coach that is desired. If the potential user wished to buy one of these existing models they would need to conduct a cost-benefit analysis, in order to find the cheapest model that fits their needs. The most logical way to do this is based on the functionality of the Speed Coach, as the number of features built in to the device increases with price. A table comparing functionality to price is included as **Appendix 6**. The potential user would need to go through these features and choose the cheapest device that met their needs/desires.

10.2 Cost-Benefit Analysis of Speed and Stroke Rate Sensing Technology

Speed Sensing Technology: The benefit of including compatibility with both an accelerometer and an impeller is that it would increase the battery life if an impeller was available (as discussed in Section 8), however it would also increase the cost of the system.

The current idle time before automatic power off is either 8 or 17 minutes, while the entire battery life of the batteries in question is 600 hours, at a cost of \$5/battery. Assuming that the device is left to automatically turn off every session, this would mean an extra 32 or 68 minutes of run-time per week for an average rower, who rows four times per week. This leads to one extra battery being required over the 16.5 year time span illustrated in Figure 8. As it is unlikely that a rower will continue to use their Speed Coach for longer than this, it can conservatively be estimated that the cost of not including this compatibility is \$10. It is assumed that to program the device to be compatible with an impeller and a 3-axis accelerometer would not incur additional costs, as the software required already exists in separate current models. 3-axis accelerometers themselves can be found online for as little as \$2.95 (*SparkFun Electronics, 2015a,b*), and many more advanced chips sit at around \$10 (*AliExpress, 2015*).

This analysis is predicated on the assumption that the inclusion of these features would reduce idle time before power-off to zero. While this is unrealistic, even a reduction of half the idle time would still save the user money, assuming that the cheapest accelerometer was implemented. Therefore the inclusion of a 3-axis accelerometer, along with software compatible with both the accelerometer and the impeller is recommended for future Speed Coach models (Recommendation 8).

Stroke Rate Sensing Technology: In order to determine the validity of including a piezoelectric sensor in the Speed Coach system, it was first found that piezoelectric sensors usually cost between \$10 and \$20 each (*AliExpress, 2015a,b*), (*Green, M, et all, 2015*). The current stroke rate sensing technology of an accelerometer or seat magnet have been shown to be slightly inconsistent with each other, and often sensitive to external conditions (see Section

9). It is highly important that a rower has an accurate idea of their stroke rate, as stroke rates are often capped during training in order to ‘level the field’. Furthermore, rowers usually plan their races around rowing at certain rates at different points during the race. Inaccurate data would therefore hinder the execution of these plans.

A potential instability issues that might arise from including a sensor of this kind on only one of the riggers is worth noting. If this issue was to prove significant it could easily be counter-balanced by a second sensor on the other rigger. Alternatively, any other very small object could be attached to the other rigger to supply the counter balance at a cheaper price.

Given the importance of accurate stroke rate data, it is recommended that this feature is included in future Speed Coach models (Recommendation 10).

10.3 Pay-back Period of Including a Photovoltaic Strip in the Speed Coach Case

It was found that the cost of thin-film photovoltaic cells was \$0.50 per Watt in 2013 (*XE, 2015*). Given the value of 0.12W found in Section 7, the expected cost of including the cell is \$0.175. It was stated in Section 6 that the batteries in this system have a capacity of 220mAh, which can be converted to ‘Wh’ using the process described in that Section. Thus it was found that the inclusion of the photovoltaic cell would lead to an increase in battery capacity from 0.66Wh to 0.78Wh (an increase of 21%). Therefore the pay-back period of this inclusion is expected to be 2 months, if the additional energy produced by the strip is used solely as an additional power source for the backlight (which would be done as the backlight battery is expected to have a shorter life-span, as discussed in Section 6). This will increase the time between battery replacements, improving the design from a time perspective. Finally, it is worth noting that the cost of photovoltaic strips is not constant, and is expected to fall further with time (*EnergyTrend, 2015*), (*CleanTechnica, 2014*). This indicates that the pay-back period of this inclusion will vary, but is expected to follow a downward trend. This inclusion was therefore listed as Recommendation 9.

11 Conclusion & Next Steps

The analysis in this report was undertaken with the aim of identifying improvements that could be applied to new models of Speed Coaches. The analysis focused on areas of current Speed Coach designs where improvements could be made and what those improvements would be, while the actual implementation of these improvements was not analysed beyond an expected overall time frame. It is expected that the implementation and distribution of Speed Coaches with these improvements would take approximately 1 year. This analysis led to a list of 10 recommendations that focused on improving current Speed Coaches from a range of analytical angles. The next step to be undertaken following this report would be to examine how these recommendations could be enacted, and work towards implementing a new Speed Coach design that incorporated these improvements within the stated time frame. An example of the sort of analysis that needs to be taken after this report is the Design of Experiments analysis outlined in Section 7.1. Completing this part of the analysis will allow a suitable case material to be selected.

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13 Appendix

1. Survey

Q1) Do you regularly use a Speed Coach when rowing?

- a) Yes
- b) No

Q2) What age category do you row in?

- a) Juniors
- b) Opens
- c) Masters

Q3) Are you a coach or a rower?

If you are a coach and members of your crew do use Speed Coaches, it would be great if you could finish this survey to give me an indication of how helpful you find Speed Coaches, and what changes you would like to see

- a) Coach
- b) Rower

Q4) If you do not regularly use a Speed Coach when rowing, why not?

- a) I don't row enough to make it worth while
- b) I'm not competing enough/ at a high enough level to make it worth while
- c) They're just too expensive
- d) I've never really considered it
- e) Other: *Please Specify*

Q5) What is the highest level of rowing competition that you have participated in?

If you answered 'no' to question one, please finish the survey after completing this question

- a) I don't compete
- b) Local regattas
- c) Interstate regattas
- d) National regattas
- e) International regattas
- f) Other: *Please Specify*

Q6) How important do you believe Speed Coaches are to your overall improvement?

Compare this to other sources of improvement. Eg. Good diet, endurance training, fancy new carbon fibre oars, etc.

- a) It is the most important part of my training, I can't train without it
- b) I find it very helpful, but it isn't the most important thing
- c) If I didn't use a Speed Coach my performance may be a little worse
- d) I don't find it that helpful, but I'm happy I use it
- e) It's a waste of money, I have one and don't use it
- f) My Speed Coach is the bane of my existence

g) Die Speed Coach, die

Q7) Please select the top five features you think are most important:

- Stroke Rate
- Wireless Stroke Rate
- Stroke Count
- Chronograph
- Time
- Speed
- Wireless Speed
- Impeller Speed
- Distance
- Heart Rate
- Split Memory
- Programmable Workouts
- Computer Upload
- Backlight
- Rechargeable Batteries
- User-Replaceable Batteries
- Waterproof
- Floats

Q8) Please list as few or as many ways that you can think current Speed Coaches can be improved
Eg. Longer battery life, smaller size, extra features, improvements on features listed above, etc

Q9) In what ways do you feel that using a Speed Coach has improved your performance?
Eg. keeping pace in a race, training at certain stroke rates, etc

2. Final Output of Python Script (seperate script used for analysis of Coach data)

SURVEY RESULTS (ROWER DATA)

Number of Respondants: 54
Number of Coaches: 4
Number of Rowers: 49

AGE CATEGORY V SPEED COACH USE

Juniors who use device: 17
Juniors who dont use device: 4
Opens who use device: 18
Opens who dont use device: 6
Masters who use device: 3
Masters who dont use device: 0

EXPERIENCE V SPEED COACH USE

Non-competitors who use device: 1
Non-competitors who dont use device: 1
Local competitors who use device: 1
Local competitors who dont use device: 2
Interstate competitors who use device: 16
Interstate competitors who dont use device: 3
National competitors who use device: 14
National competitors who dont use device: 5
International competitors who use device: 7
International competitors who dont use device: 0

EXPERIENCE V VALUE PLACED ON SPEED COACH (0 = no value, 7 = max value)

Average rating of rowers who do not compete: 0.0
Average rating of rowers who compete locally: 5.0
Average rating of rowers who compete interstate: 4.25
Average rating of rowers who compete nationally: 5.071428571428571
Average rating of rowers who compete internationally: 4.857142857142857
Overall rating: 4.564102564102564

BRAND OF SPEED COACH USED

Total number of rowers who use Speed Coach: 38
Number of rowers who use Nielson-Kellerman devices: 35

REASONS THAT ROWERS DO NOT USE SPEED COACHES

Not available to me
They're just too expensive
Sometimes forget
I've never really considered it
I'm not competing enough/ at a high enough level to make it worth while
I've never really considered it
I find them distracting
sometimes they are unavailable (we have around 3 in the whole squad)
I've never really considered it
I've never really considered it
They're just too expensive
I've never really considered it
Training on speeds and rates. Racing on stroke rate.
They're just too expensive
They're just too expensive
Na
I'm not competing enough/ at a high enough level to make it worth while

3. Suggestions for Improving Current Speed Coaches (based on Survey Q8)

- Longer battery life
- thinner
- Lighter
- pace boat
- Longer battery life
- easy to read from different angles eg, from the finish and from the catch.
- smaller size
- groovy patterns and designs on the weird rubber cover case thing
- more features visible, on the single screen at one time, heart rate shows on the screen
- smaller size, groovy patterns and designs on the weird rubber cover case thing
- more features visible on the single screen at one time
- heart rate shows on the screen
- longer battery life
- more attachments to the boats so they can work with other riggers
- Longer battery
- Waterproof
- It's sometimes hard to see the screen when I'm rowing
- Easier to attach to boats
- Longer battery life
- float in water
- have a light built in
- longer battery
- quicker responses to changes in rate and speed
- Longer battery life
- Better holder
- Extra features
- ability to download workout pieces
- smaller size

- Power/force curve
- Touch screen
- Larger display
- Ability to upload training data to websites such as training peaks or strava.
- Being able to set a workout like on a c2
- Better wireless connectivity and range for a coach unit.
- Antennas which are vital for coaching so stroke coaches can be paired, are fragile and broken easily by rowers
- Transmission distance on paired stroke coaches is low, creates difficulties for training multiple crews.
- Longer battery life for gps speedcoaches/ better battery life in cold weather
- Speed smoothing could be adaptive based on changes in rate eg 3 stroke when rate is constant, 2 stroke as it increases - there's about a 5 stroke lag
- export to computer for statistics
- set favorite pieces on the stroke coach eg 2km piece of 10min piece and then save this stuff so I can check later such as online.
- Not floating is insane
- They're hard to get into their holders. I use a gps one so the holder input isn't even necessary
- They could be lighter, Memory recall is not intuitive
- Programmable work out would be great.
- program pre set courses using GPS coordinates enterable with online
- user friendly software
- Smartphone like 'mapping' feature - can prescribe a course to follow if you select a distance from example
- Be downloadable to the computer to track progress either via a cable or wifi/bluetooth
- definitely longer battery life
- lower price
- Should float
- It would be cool if you could link up with training partners, like maybe people in other singles so you could see each other's splits. Might stop rate cheaters too!
- NK GPS Stroke Coaches need longer battery life. For regular training they should only need charging every 2 weeks.

- Bigger unit
- it needs to be able to float
- Smaller in depth
- Cheaper
- Most heart rate monitors now use ANT+, but Speedcoaches are only compatible with bluetooth, which limits the options available. While it would be great to get something like the power meters available for cycling, it probably wouldn't be viable, because of the cost. What should be feasible, is a setup with an impeller and something like the powerpod (<http://www.dcrainmaker.com/2015/08/first-powerpod-power.html>) which, between them, could estimate power. It would be good to be able to program them in a similar way to a Garmin cycling computer. When riding, my Garmin Edge 810 will alert me if my Heart rate goes below 140 bpm and I can set alerts for cadence and speed as well.
- cheaper, better session analysis similar to a garmin bike computer
- Extremely long battery life is essential, current GPS stroke coaches can last over a week of full time training between charges
- it would be great to have this and also to be able to get rower specific info on training zones
- Also, if it had force curves on it as you can get on that iPhone App that would be very helpful to measure your stroke efficiency.
- touch screen would be cool
- its hard to see the screen at the catch

4. Opinions of Current Speed Coach Benefits (based on Survey Q9)

- I find it helps as a guide, I try and stay away from Speed Coaches in races as it makes me look down quite a bit which in turn stuffs up my technique.
- Keeping a steady state while training. Seeing the difference in speed while focusing on different aspects of the stroke.
- It shows me the rate of my stroke which gives me a feel of a good race pace and also the amount of pressure through the water compared to the rate of the stroke.
- keeping the stroke rate constant during training/racing, being able to see my speed during training, feels pretty professional to use one, know what split i am capable of holding in a race
- I it has more improved my general rowing with my awareness of what rates an splits feel like
- its easier to record how many kms u do, and speed/distance
- Helps me maintain my stroke rate

- knowing what my rate is, being able to predict rate, training at levels , knowing my limit
- keeping the rate
- Preparing for racing through knowing how fast I'm going, being able to focus on distance per stroke much better, training at certain stroke rates
- keeping pace (speed/rate) during racing, keeping pace (speed/rate) during training, training at a certain speed/stroke rate, training using the chronograph or using distance
- Interval training and keeping to a set workout. Being able to plan a session in advance and implement it on the water whether based on speed distance or time.
- Keeping stroke rate for sessions. Monitoring race dynamics. Achieving target splits.
- Real-time performance check, Make session plans based upon crew performance, Punishing the students!
- Keeping pace and being aware when speed changes, for good or worse. In addition, I sometimes feel like a Speed Coach is a distraction.
- Constantly seeing my split/500m motivates me to keep the pressure on
- allows to work at set rates/ speeds for more efficient training, Essential for racing feedback, speed/rate
- being able to see my rate is extremely helpful.
- Stroke rate and speed are essential, speed particularly so. Immediate feedback on technical changes.
- rate is critical, but shouldn't be too much focus. Just another tool.
- Track consistency between sessions, track progress, maintain effective split drop as rating climbs
- they're extremely helpful with race starts and maintaining the same rate during a piece
- Helps me keep the rate high, if it was up to me it would always be rate 20
- It is hard for rowers to know what the 'right feeling' is or whether I'm 'rowing well'. When it comes down to it all that matters is if the boat is moving quicker, and that is why the speed
- coach is so important. It allows you to sanity check the technique changes you are grappling with against the best measure we have, speed.
- Knowing exactly what speed i am doing instead of guessing
- Having speed and heart rate in front of me keeps me more honest in training. If I see my speed or heart rate drop during a piece, then I know that I'm slacking off and need to start pulling harder. During racing, it helps me get to my goal split, rather than coming out of the blocks 5 or 6 splits too fast, leading me to blow up before the end.
- Training on speeds and rates. Racing on stroke rate.
- It allows me to keep an eye on my pace and stroke rate which is useful for training and racing

5. Full Transcript of Interview with Current Australian Rower Conducted over Facebook

Q: Hey mate, in the spirit of the same project that required a survey, i also need to conduct an interview.. As you've competed overseas as well as locally you were the best person i could think to ask. Do you reckon you could send me answers to these two questions at your leisure?

When you attend regattas in Australia and overseas, do you notice any change in what Speed Coaches rowers use, or how they are used?

What brand of Speed Coach is the most common that you come across?

I hope this isnt too much trouble.

A: All good buddy.

The only change I've noticed has been the move from the traditional impeller Speed Coaches to the GPS Speed Coaches. I think the big reason for this has been, ease of transferring from one boat to another eg being able to use it in a boat that doesn't have the wiring harness for rate/speed.

Also the ability to use in other seats in the boat not traditionally associated with having a Speed Coach

I would definitely say the GPS version is by far the most popular because of its versatility (reasons stated above)

Also provides more bang for your buck, eg includes heart rate in some models

Q: Thanks mate! that's actually helpful for a section ill have to write a bit later. I was more fishing for the actual brand of Speed Coach that people are using.

A: ahh ok, yeah everyone uses NK, they have the market stitched up.

Q: Yeah, I expected as much, just thought I'd check that there wasnt some overseas brand I haven't heard of. Thanks for your help, is it ok if i add this discussion into my assignment? I won't use your name or anything like that

A: Yeah all good

6. Comparison of ‘Features Included’ Versus ‘Price’ of Current Nielson-Kellerman Speed Coaches

Feature	\$199	\$319	\$399	\$519	\$619
Stroke Rate	Y	Y	Y	Y	Y
Wireless Stroke Rate	Y	Y		Y	Y
Stroke Count	Y	Y	Y	Y	Y
Chronograph	Y	Y	Y	Y	Y
Time		Y	Y	Y	Y
Speed		Y	Y	Y	Y
Wireless Speed		Y	Y		
Impeller Speed	Y	Y	Y	Y	Y
Distance	Y	Y	Y	Y	Y
Heart Rate			Y		Y
Split Memory	Y	Y	Y	Y	Y
Speed Memory	Y	Y	Y	Y	Y
Programmable Workouts				Y	Y
Computer Upload				Y	Y
Real-time Data Feedback				Y	Y
Backlight	Y	Y	Y	Y	Y
Rechargeable Batteries		Y	Y	Y	Y
User-Replaceable Batteries	Y		Y		
Waterproof	Y	Y	Y	Y	Y
Floats				Y	Y
Total	11	14	15	17	18

Table 4: Features v Cost of Nielson-Kellerman Speed Coaches