An Analysis on whether Photographers really need a Dedicated Travel Camera

Individual Portfolio

ENGN 2226

Systems Engineering and Analysis

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W09

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Abstract

Photographers often demand the best equipment and each piece must be suited to their current surroundings even if they would never use that piece of equipment again. This report aims to discover if photographers really need a separate camera to travel with. Often seen as another expense, the only 2 key concerns are size and battery life. The report will cover topics such as Human Factors for anthropometrics and ergonomics, a Design of Experiments to test battery usage, which is accompanied by a Sankey Diagram and finally the economic cost of buying a new camera system. The report has based these analysis techniques on two cameras, the Canon 60D and the Canon M and has found it is not worthwhile to purchase a travel camera of this caliber if the 60D is already possessed.

Introduction

Typically if a camera is able to capture an image, the camera is considered to be suitable for its purpose. However, the conversion from film to digital meant vast improvements with sensor technologies and lens optics. This paradigm shift meant photographers can search for that 'perfect' image and this lead to purpose function dedicated cameras separated into roughly 2 different consumer categories,

- DSLR - A DSLR camera uses a design whereby a mirror in front of the sensor, angled at 45 degrees provides an accurate image through the viewfinder, before pivoting out of the way, when the shutter button is pressed for the sensor to capture the image (*Appendix 1.1*). Different properties may be changed independently such as aperture (controls how much light is let in through the lens), ISO (so called 'film speed' it is a measure of the light sensitivity of the sensor. A higher ISO number requires less exposure to have the same image density as a slower film) and shutter speed (length of time the sensor is exposed to light. The range of DSLR cameras is from amateur to professional, with price ranges from a few hundred to many thousands (Shopbot, 2013). Principally designed for accurate capture of the scene seen by the photographer, these cameras are for those who desire and require quality photos enabled by the independent settings.

- Compact/Point and Shoot – A compact camera is designed primarily for simple operation. Many adjustable features are locked or fixed such that the computer within the body of the camera completely exposes the scene. This is often advantageous for ease of operation, but often the onboard computer cannot always correctly expose, especially if the scene is either too bright or too dark (Elise, 2009). Along with a built in flash, cameras in this category are small and light.

Looking to travel at the end of year, a university student is deciding on a camera system to take on his journey. The overseas trip will bring him to Hong Kong and Mainland China for a total of 2 weeks. In this time, the student plans to document anything and everything interesting he sees through his camera. Currently, the student owns a Canon 60D APS-C DSLR, which he uses for photography work as well as hobby activities on the weekend. The proposed plan is to purchase a smaller more compact camera that can produce quality images similar to a DSLR – the desired camera is a Canon M. The options are to either use the 60D for travelling, or to purchase the Canon M and leave the 60D at home.

The Canon M is marketed as a 'DSLR camera in compact body' (Canon, 2013). It is a Mirror-less Interchangeable Lens Camera (MILC) and by design, the weight and complexity of controls are reduced compared to a DSLR. Most conventional camera buttons are replaced by a large 3-inch touch screen on the back panel, which can be used to selectively focus the image before capture. The biggest innovation is the new proprietary Canon M mount for lenses is compatible with the EF and EF-S series lenses with an adaptor. This is allows a relatively new system access to a well developed and established series of lenses. Reviews have suggested that the auto-focus is rather slow (Hession, 2013). However, the backwards compatibility with lenses along with a sensor that is exactly the same size as the 60D, means theoretically, the Canon M image quality should be equal to the 60D, but in a smaller package.

The Canon 60D is the first DSLR to come with a 'vari-angle' tilt screen display (Canon, 2013). This enables more frequent use of the live-view option and allows the user to have a more creative edge whilst filming. Its size is larger than the XX0D series of Canon DSLRs and thus it is also heavier (Canon, 2013). A newly developed battery, the LP-E6, suggests the 60D can take up to 1100 images without live view or flash operating. Compared to a battery life of 200

to 250 shots (Imaging-Resource, 2013) for the Canon M, the larger and more powerful 60D battery may be more suitable for travelling, despite the size of the camera.

Even with the abundant information from reviews of each system and from manufacturers, testing between cameras is often hypothetical and purely based on either first impressions or speculations. For example, many reviewers say that due to the size of the sensor in a certain camera, the images produced will be better. However they do not say by how much, just that the image will be better – and this is a very subjective measure of photo quality! Thus, by applying the systems analysis topics developed in ENGN 2226, an objective decision can be made to determine whether travelling with the Canon M or Canon 60D is more appropriate.

The key aspects of a photographer's travel camera is that it must be robust, sturdy, unobtrusive to carry, have a decent battery life and overall it must have the ability to take quality pictures no matter the conditions, be it weather or location related. The analysis will be conducted from the perspective of a photographer who has sound knowledge in their field and is able to produce creative and eye-catching images.

To explore the characteristics of an ideal travel camera, human factors are taken into account. This topic explores how easy and comfortable a product is to use. For the camera to function a battery pack has to supply the power required and this analysis is done through a Design of Experiments test to determine which camera function most heavily impacts battery use. Following this method, it is also possible to work out how many batteries are required on a typical travel day and thus work out the cost of having these batteries on hand along with the cost of the camera over its entire lifecycle. Finally, the cost of purchasing the Canon M is analysed and a queue theory analysis is conducted to find areas where time could be saved to decrease waiting times. Finally a recommendation will be made to decide it the Canon M is a worthwhile investment.

1. Anthropometrics and Ergonomics of the two cameras

If a camera is comfortable to use, it not only enhances the user experience, but it also increases productivity and allows the photographer to be more efficient. The productivity increases due to a more intuitive layout of software menus on the camera and efficiency is

increased since less time is spent finding a particular setting/control. These factors are very important for someone whose income is purely from taking photographs. The camera controls/dials need to be within easy reach whilst a firm grip can be maintained on the camera. By conventionally holding the camera in the right hand (*Appendix 1.2*) and with the left hand supporting the bottom/lens (*Appendix 1.2*), it is possible to measure the distance moved to complete a sequence of common functions. The right palm generally doesn't move and the shortest distance moved for both hands will prove to be the most efficient.

Table 1.1: Canon 60D Hand Movement for the different sequences of functions

Canon 60D Hand Movement							
Path 1	*Power On*	*+2 on ISO*	*Zoom*	*Press Shutter*	*Review Image*	*Delete Image*	**Total**
Distance (mm)	L 15	R 30	L 80	R 0	R 60	L 50	**R 90 L 145**
Path 2	*Power On*	*Aperture*	*Exposure (0 to +1)*	*Press Shutter*	*Power Off*	*Battery Out*	
Distance (mm)	L 15	R 30	R 65	R 0	L 60	R 100 L 70	**R 195 L 145**
Path 3	*Power On*	*Enable Flash*	*Switch to aperture priority*	*Press Shutter*	*Review Image*	*Power Off*	
Distance (mm)	L 15	L 20	L 85	R 0	R 60	L 60	**R 60 L 180**

Table 1.2: Canon M Hand Movement for the different sequences of functions

Canon M Hand Movement							
Path 1	*Power On*	*+2 on ISO*	*Zoom*	*Press Shutter*	*Review Image*	*Delete Image*	**Total**
Distance (mm)	R 20	R 50	L 30	R 0	R 25	R 40	**R 135 L 30**
Path 2	*Power On*	*Aperture*	*Exposure (0 to +1)*	*Press Shutter*	*Power Off*	*Battery Out*	
Distance (mm)	R 20	R 40	R 35	R 0	R 20	R 70 L 70	**R 185 L 70**
Path 3	*Power On*	*Enable Flash*	*Switch to aperture priority*	*Press Shutter*	*Review Image*	*Power Off*	
Distance (mm)	R 20	R 30	R 50	R 0	R 25	R 20	**R 145 L 0**

Having no buttons on the left hand (LH) side of the screen meant the Canon M hand movements are much smaller than that of the 60D. This conclusion was expected due to the smaller size of the Canon M. It can be seen the LH is only used to support the camera and

operate the zoom on the Canon M. Although this may seem beneficial, it means the right hand (RH) has to operate the camera as well as hold onto it. This places a strain on the three gripping fingers, as the thumb and pointer have to control the camera. With not much of a grip to hold onto due to the compact body shape, one could imagine the strain after continuous operation.

The Canon 60D somewhat evenly spreads the controls between the LH and RH, even though most of the buttons are on the RH side. This reduces the workload of the RH, but even so, the fingers on both hands are moving much further compared to the Canon M. It was noted that in Path 1, the stretch from the shutter position to changing ISO is actually quite a long distance of 30mm. On average, the RH pointer metacarpus joint can only move about 20 degrees equating to roughly 20mm laterally (AndrewS, 2012). For someone with larger hands/longer fingers, this may not be a problem, however it certainly does not fit the 'average'.

Anthropometric data suggests that the hand width (measurement across the knuckles) is 84mm and 74mm for males and females respectively (The Average Body, 2013). Allowing room for the shutter and often a protruding wheel for adjustments, often photographers complain that consumer DSLR cameras are too small to hold in their hands and have to purchase a battery grip (*Appendix 1.3*) to further extend the grip area. The increased size impacts the camera's ability to fit in a bag, which is essential for travelling. The fingers provide the clench whilst the thumb opposes and allows the hand to grip. Frequently a problem on small cameras, the grip is not large enough and the fist position is not formed, rather the fingers try and touch the wrist. Whilst this may feel comfortable to the user when not in use, having to constantly reposition the hold places unnecessary stress on the hands. This is known as a forced hold. A strong, firm and relaxed grip is preferred and is important for holding the camera still, especially if a long lens is attached (AndrewS, 2012). Therefore, the 60D will be more comfortable whilst shooting, but the Canon M will be less of a burden when not shooting.

Whilst size of the camera is definitely important in a travel camera, there is another crucial factor and that is the battery life. Traveling means exploring new places and often these places may not have electrical outlets, thus it is sensible to analyse how many batteries one needs to carry on any particular trip.

2. Battery Life under Different Uses - Design of Experiments

The number of batteries a photographer has to carry is often subjective. Some users carry less and some carry more. However, circumstances may arise where packing to a weight limit is inevitable and certain items will have to be left behind. By carrying redundancies, it does limit the unfortunate happening, but it also wastes space and the extra weight will be also be a burden if traveling with a backpack. Although carrying spare batteries is seen as a preventive and often necessary procedure, if the user knew which functions on their camera consumed the most power, they would be conscious as to limit using these functions in general and if their battery was low to prolong battery life.

To test the different functions on the camera, a partial Design of Experiments (DOE) analysis is used. This concept allows each variable to be tested against the outcome and other variables to see which one is the most influential on the output. The variables chosen in this DOE are focus (manual or automatic), flash (on or off), live view (on or off) and picture quality (JPEG or RAW). Both 60D and M batteries are measured at the start (*Figure 2.1*). 20 shutter actuations with 3 seconds in between is the control variable for each test. The battery is completely charged after each trial. The results for both cameras are shown in the *Appendix 2.1*. The DOE graphs are displayed below (*Figures 2.2 and 2.3*).

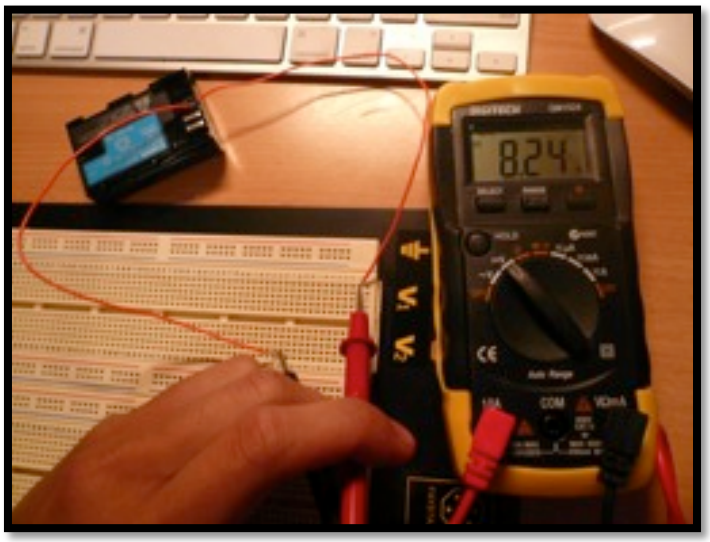

Figure 2.1: Measurement of the battery used in the 60D. Exactly the same method was used to measure the Canon M battery. Image taken by author.

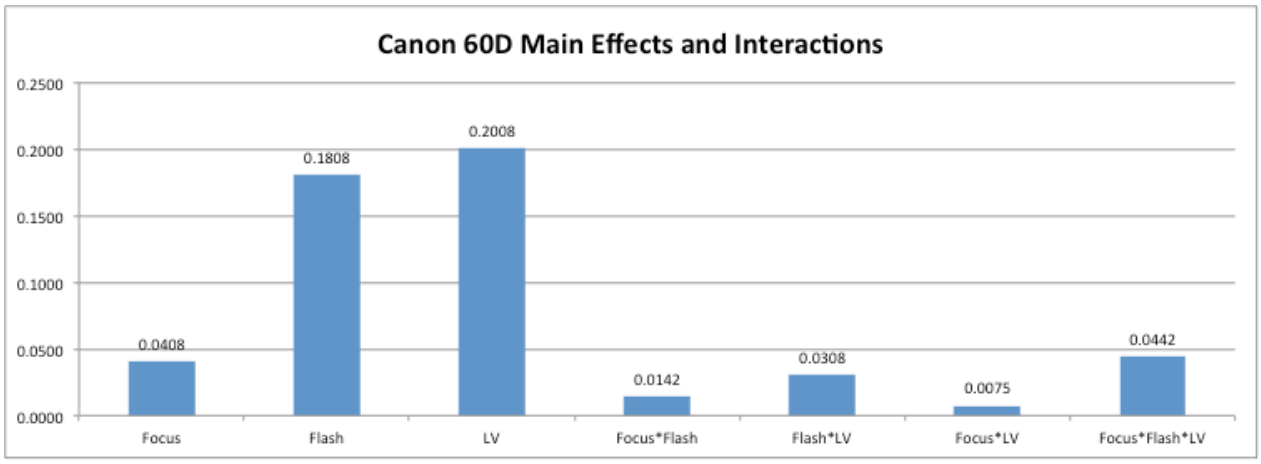

Figure 2.2: A summary of the most influential function that causes battery drain in the 60D

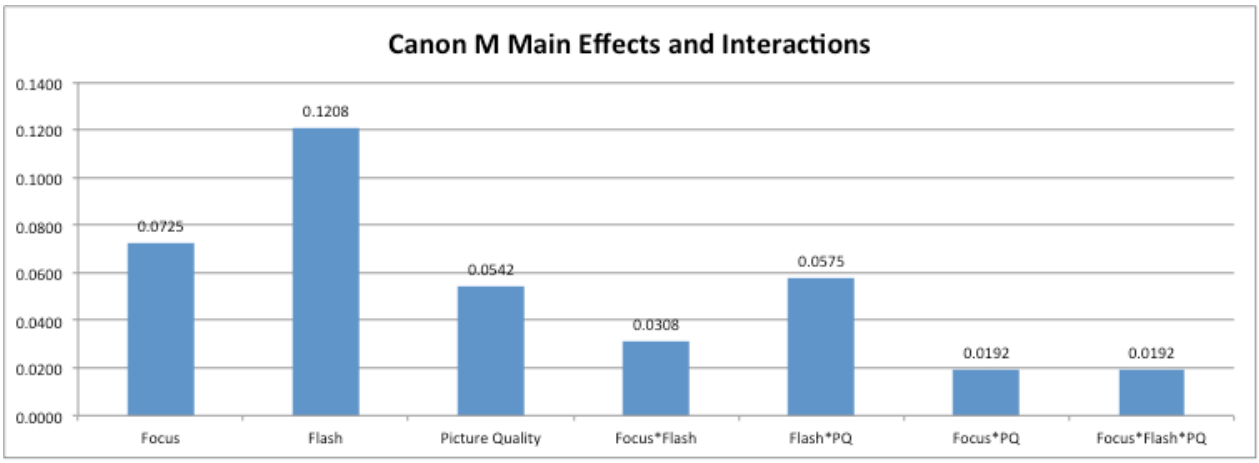

Figure 2.3: A summary of the most influential functions that causes battery drain in the M.

The Design of Experiments showed that the Live View in the 60D and using the Flash in the M drained the battery the most. If every shot were taken in the most energy consuming state, the 60D impressively lasts 643.3 shots compared to a claimed 1100 (59%) (Imaging-Resource, 2013) and the Canon M would last 60 shots out of a claimed 230 (26%) (Imaging-Resource, 2013). These values are calculated by finding the difference in voltage, Δv, after taking the 20 actuations under each condition. Then have the initial voltage divided by Δv to find the number of actuations possible. The output is the number of actuations possible under these conditions. This large difference may be down to the different ratings of current for the two batteries where the 60D's is higher. Also the Canon M does not have a built-in flash like the 60D. Therefore it's own external flash (*Appendix 2.2*) had to be used. This meant separate batteries power the flash, however it was still the most power-consuming feature. In the 60D, the live view consumes power almost equal to that of the onboard flash. 'Picture quality' was

tested in the M and not in the 60D since the M does not have a viewfinder (Canon, 2013) and thus the 'live view' option is always enabled and thus pictures cannot be taken with the screen off. This would explain why there is a dramatic decrease in battery life as each of the tests was done with 'live view' on.

To further expand on battery usage, Sankey diagrams are drawn to graphically show where power is being used for both cameras. It will also highlight the smaller functions, which could be turned off or disabled to further lengthen battery life.

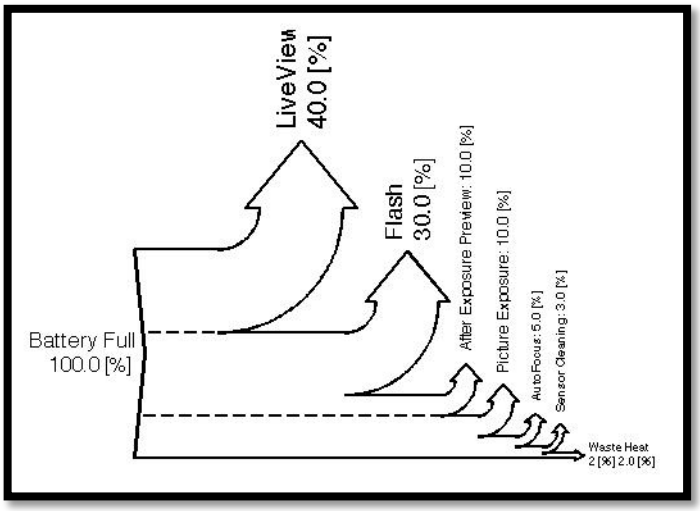

Figure 2.4: Sankey Diagram for battery usage in a Canon 60D. Data is from the DOE and figures are rounded to the nearest percent. Enlargement in Appendix 3.1.

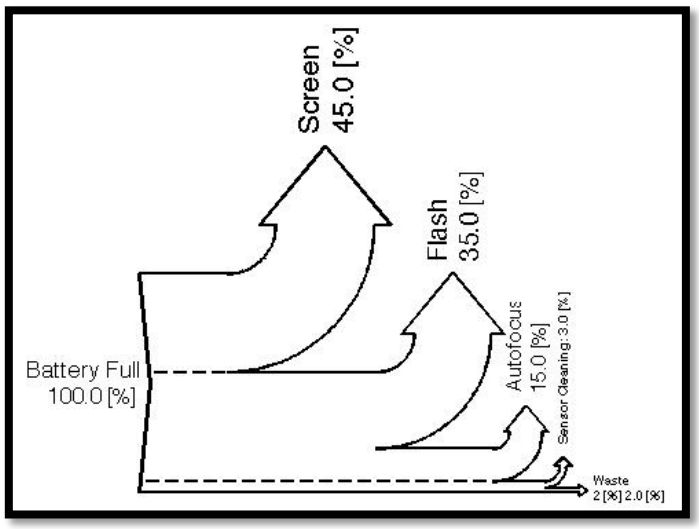

Figure 2.5: Sankey Diagram of the battery in the Canon M. Data is from the DOE and figures are rounded to the nearest percent. Enlargement in Appendix 3.1.

From the Sankey Diagrams in *Figures 4.4 and 4.5*, both of the diagrams show a rough Pareto principle where a small amount of the causes actually contribute to majority of the problem. However in this situation, the causes are the ways in which the battery is used and the problem is the depletion of the full battery. For the 60D, 42% of the causes produce 80% of the battery use and 80% of the battery drain is accounted for by 40% of the causes in the Canon M.

In summary, the 60D outperforms the M in regards to battery life. It accomplishes more in a single charge and this is important in a travel camera since power outlets are not always available. Even using these features, the battery life in the 60D is still quite good. On the other hand, the Canon M power supply falls dramatically to roughly one-quarter usability. To match the 60D in terms of battery life, a recommended 4 batteries for every single 60D battery must be carried. Batteries are expensive since they are not a standard AA dry cell, rather a sophisticated shape proprietary Li-ion battery and thus it is not always feasible to have this many spare batteries so a compromise is inevitable.

3. The Life Cycle Costing – An Economic Analysis

By finding the optimum number of spare batteries in the previous section, it is possible to evaluate the cost of them over the life of owning the camera. This leads into the Life Cycle Costing (LCC) analysis whereby the cost of the product over its entire lifecycle is realised. Most consumers are concerned with the initial upfront cost however it is the accessories, maintenance, upkeep and extras costs that will contribute mainly to expenses (Oslon, 2013). Especially in photography where often the choice of camera body is not really as important as the lenses because the lens is the lead contributing factor for image quality (Oslon, 2013). The lenses themselves can often cost more than the body they are attached to. Sometimes costs are hidden behind claims such as warranties, 'money-back' guarantees and special offers. For example a recently purchased product includes 3 years warranty, however it is only valid in the country of manufacture, and postage costs render the faulty product now obsolete. Generally, the lifetime of a camera is dependent on whether the model is superseded, user obsolescence or damages. Therefore, for this analysis it will be assumed the camera will last 3 years as this is roughly the period of time a new model is unveiled (DPReview, 2013).

Table 3.1: LCC analysis of the 60D ($AUD). Sources: (Canon, 2013), (TEDS, 2013), (DigitalRev, 2013), (Amazon, 2013) and (JBHIFI, 2013).

	Cost Component	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Acquisition	60D Camera Body (Avg. of 3 sources)	714.50	0	0	714.5
	50mm f/1.4 Lens (Avg. of 3 sources)	400	0	0	400
	430EX ii Flash (Avg. of 3 sources)	279	0	0	279
	Computer (Apple MacBook Pro)	1700	0	0	1700
	Manfrotto Tripod	200	0	0	200
	Backpack/Carry bag	200	0	0	200
	4 Sandisk Ultra SDHC @ 47 each	94	47	47	188
	3 Spare Batteries @ 80 each	160	80	0	240
	4 AA Rechargeable Batteries +Charger	40	0	0	40
	Filters	30	0	0	30
	Remote Trigger	25	0	0	25
Maintenance	Cleaning/Servicing @ 80/year	80	80	80	240
	Computer Servicing @ 300/Semiannually	300	0	300	600
Software + Hardware	Backup Hard drives (1TB)	100	0	0	100
	Adobe Lightroom 5	186	0	0	186
Refinement + Disposal	Neck Strap	30	0	0	30
	Resale Value (Body, Lens and Flash)	+1114.67 (80%)	+905.67 (65%)	696.67 (50%)	+696.67
			Total after 3 years		4843
			Total after resale of Body, Lens and Flash		**4147.17**

The LCC completed in *Tables 3.1 and 3.2* assumes the user will also require a laptop upon purchase of this new camera to accommodate the larger files sizes and quicker throughput for photos. From *Tables 3.1 and 3.2*, it can be seen that most of the cost is in the first year of ownership. This large upfront cost can be quite daunting and is the reason why people pick up

compact point and shoot cameras instead. However, these upfront costs may be lowered and this is done by purchasing the 'Software + Hardware' items later in the life cycle. The demand for these additions is often not required in the first year of ownership especially if the user is still familiarizing themselves with the camera. This is applicable to both cameras.

Table 3.2: LCC analysis of the Canon M ($AUD). Sources: (Canon, 2013), (TEDS, 2013), (DigitalRev, 2013), (Amazon, 2013) and (JBHIFI, 2013).

	Cost Component	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Acquisition	M Camera Body (Avg. of 3 sources)	400.30	0	0	400.30
	22mm f/2 Lens (Avg. of 3 sources)	192.50	0	0	192.50
	90EX Flash (Avg. of 3 sources)	129	0	0	129
	Computer (Apple MacBook Pro)	1700	0	0	1700
	Manfrotto Tripod	150	0	0	150
	Backpack/Carry bag	150	0	0	150
	4 Sandisk Ultra SDHC @ 47 each	94	47	47	188
	8 Spare Batteries @ 46 each	184	92	92	368
	2 AA Rechargeable Batteries + Charger	30	0	0	30
	Filters	30	0	0	30
Maintenance	Cleaning/Servicing @ 40/year	40	40	40	120
	Computer Servicing @ 300/Semiannually	300	0	300	600
Software + Hardware	Backup Hard drives (1TB)	100	0	0	100
	Adobe Lightroom 5	186	0	0	186
Refinement + Disposal	Neck Strap	30	0	0	30
	Resale Value (Body, Lens and Flash)	+577.44 (80%)	+469.17 (65%)	360.9 (50%)	+360.90
			Total after 3 years		4373.80
			Total after resale of Body, Lens and Flash		**4102.90**

The LCC of the two cameras are really similar, only differing by $45 after the resale of body, lens and flash (BLF). The reason for this is, despite the initial higher cost of the BLF, the higher end components in Canon's range often have a good resale value. For example, most lenses in Canon's Luxury range often hold their initial cost and most second hand prices are around 80% of the original retail price (The Digital Picture, 2013). However for this analysis, the same depreciation rate is used since it seems more realistic for a fluctuating market and the cameras and lenses selected.

For the current situation where the photographer already has the 60D, it could be assumed the computer and camera hardware, like the tripod, is already purchased. Therefore the only extra cost involved is the purchase of BLF and the associated 8 spare batteries. This brings the cost down to $1089.80. Of course having 8 spare batteries is probably an overestimate and realistically, 4 batteries is enough if the user has access to charging capabilities. This brings the cost down to $905.80. Furthermore, if the user purchases the Canon M BLF as a bundle, this brings a saving of $82 (DigitalRev, 2013) and the user will also acquire a Canon 18-55mm lens (which could be sold for ~$50). This brings the cost total down to $773.80.

The difficulty now is to decide whether an expense of $773.80 warrants the convenience of having a smaller camera, which can theoretically produce the same picture quality as the 60D. To come up with the best solution, a partial queue analysis is applied to both cameras.

4. From Off to Capture – Applying Queue Theory

When travelling with a camera, there will be situations where the photographer will have to place the camera back into their bag. This occurs during entry into old buildings, or places which prohibit the use of flash for example. When this occurs, it is likely the photographer will power off their camera. This stopping and starting will be the basis of the queue theory analysis. The waiting time between power on, the intermediate phases leading up to image capture then power down is analysed for both cameras.

Table 4.1: Response time for capturing an image on the 60D and M (Imaging Resource, 2013).

	Canon 60D	**Canon M**
	Time (seconds)	Time (seconds)
Power on to ready	0.4	2.7
Shutter Response Full Autofocus to Capture	0.253	0.894
Image Capture	0.013	1.126
Display Captured Image	0.7	0.4
Shutdown	0	0.2
Total	**1.366**	**5.32**

By looking at the total time in *Table 4.1.* It can be seen the waiting time from 'Power on to ready' is almost 7 times longer in the Canon M. This is probably because essentially it also has to activate the touch screen and enable focusing. The Canon M also takes about 3 to 4 times longer to focus automatically. Also since the focusing and framing on the M is done via the touchscreen, the longer this process takes, the additional drain on the battery.

The process of taking a photo is very much progressive/cyclic whereby after the first photo is taken, the process is reiterated to capture the next image. The start to finish nature means this is a single channel multi-phase system, whereby the camera is powered on, a photo is taken and the camera is switched off. This means the arrival mechanism is the number of times this process occurs. This process may occur once a day up to an indefinite number of times. For this this analysis it is estimated the camera will be turned on and off 10 times in the hour. This gives an arrival rate λ of 10 times/60 min = 0.167 times/min. The time for a completion, μ, for each camera is given as the total in Table 4.1. Thus, the following calculations can be made.

Table 4.2: Simplified Queue Theory for both cameras

	Canon 60D	Canon M
Expected Arrival Rate	$\lambda = \frac{10}{3600} = 0.00278 \frac{times}{s}$	$\lambda = \frac{10}{3600} = 0.00278 \frac{times}{s}$
Service Completions	$\mu = \frac{1}{1.366} \frac{times}{s} = 0.732$	$\mu = \frac{1}{5.32} \frac{times}{s} = 0.188$
Average Wait Time	$t_m = \frac{1}{\mu - \lambda} = 1.37\ s$	$t_m = \frac{1}{\mu - \lambda} = 5.4\ s$
Wait Time for 10 cycles	$t_{10} = 10 * 1.37 = 13.7\ s$	$t_{10} = 10 * 5.4 = 54\ s$
% time spent waiting for t_{10} (hour)	$\frac{13.7}{3600} * 100 = 0.38\ \%$	$\frac{54}{3600} * 100 = 1.5\ \%$

The average wait time is a little higher than the time calculated in *Table 4.1.* The average time spent at each 'phase' is roughly 0.27 seconds for the 60D and 1.064 seconds for the M. To reduce the total time for both single channel queues, the 'Display captured image' phase can be disabled. The benefit is realised when almost a second is saved in the 60D and half a second is recovered from the Canon M queue. The likely reason it takes 0.7 seconds in the 60D is that the images are displayed on one of Canon's most pixel dense screen (Canon, 2013). By eliminating this phase in the queue, it will also save on battery consumption since the screen will be used less. It is evident the screen is a major consumption of power according to the design of experiments (*Figure 2.2*) and explicitly on the Sankey Diagram (*Figure 2.4*). To improve start up time, it is also envisioned that the ultrasonic motor that cleans the sensor is also turned off. This will also allow for a quicker shutdown time and again, reduces battery usage. Another improvement is to shoot in the JPEG format, as it is the quickest to process due to its smaller file size (Stack Exchange, 2013). These are some of the outcomes/suggestions that have been developed by analysing the queue for taking a photo.

Conclusion

Using these analysis techniques, it has been determined that a dedicated travel camera is not required by a photographer already in possession of a 60D. This finding is supported by the fact that the battery life is a quarter capacity in the Canon M when compared to the 60D. Considering the sensors and imaging internals are essentially the same, it is obvious the battery capacity has been comprised to fit everything inside the Canon M. Another supporting argument for this suggestion is the start up time, image captures time and especially the autofocus time is roughly 4 times as long. This would prove to be an inconvenience whilst travelling, particularly if the camera needs to be put away such that it is switched on and off successively. The only advantage of the Canon M is its physical characteristics such as weight and size. Although not exactly pocket-able, it is much smaller in dimensions compared to the 60D and thus its weight is also less. Considering, this paper is from the perspective of someone who will not likely take photos given an opportunity, but rather make the opportunity to take photos, travelling with the 60D, even with the extra bulk, would be the better decision.

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Appendix

Appendix 1.1 – Light Path Diagram of DSLR

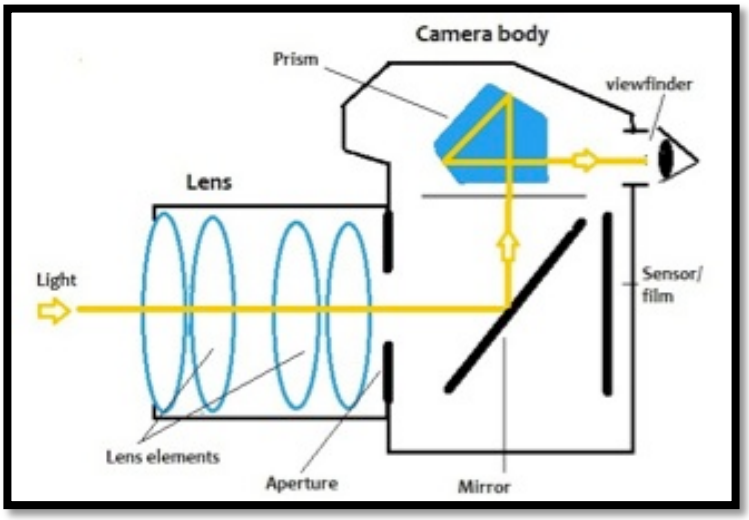

Figure A.1: Lightray Diagram of a common DSLR Camera. Source: Empowered Photographer

Appendix 1.2 – Camera Hold

Figure A.2: LEFT: *Conventional left hand grip for supporting camera.*
Figure A.3 RIGHT: *Conventional right hand grip for holding the camera.*
Images taken by author.

Appendix 1.3 - The Battery Grip

Figure A.4: The Battery grip for the Canon 60D attached. Source: (The Digital Picture, 2013)

Appendix 2.1 – 60D and Canon M DOE Results

60D DOE Analysis Results

60D DOE Legend			
Focus	Flash	Live View (LV)	Base Battery Voltage
+1 = Auto Focus	+1 = Yes	+1= Yes	8.24V
-1 = Manual	-1 = No	-1 = No	

Focus	Flash	Live View	Trial 1 (V)	Trial 2 (V)	Trial 3 (V)	Average (V)
-1	-1	-1	8.22	8.23	8.22	8.2233
-1	-1	1	8.00	7.98	8.07	8.0167
-1	1	-1	8.05	8	8.01	8.0200
-1	1	1	7.87	7.86	7.93	7.8867
1	-1	-1	8.18	8.2	8.17	8.1833
1	-1	1	7.98	8	8.03	8.0033
1	1	-1	8.04	8.01	8.07	8.0400
1	1	1	7.77	7.7	7.8	7.7567

	Focus	Flash	LiveView	Focus*Flash	Flash*LV	Focus*LV	Focus*Flash*LV
-1	8.0367	8.1067	8.1167	8.0233	8.0317	8.0200	8.0383
1	7.9958	7.9258	7.9158	8.0092	8.0008	8.0125	7.9942
Slope	0.0408	0.1808	0.2008	0.0142	0.0308	0.0075	0.0442

Canon M DOE Analysis Results

Canon M DOE Legend			
Focus	Flash	Picture Quality	Base Battery Voltage
+1 = Auto Focus	+1 = Yes	+1= RAW	7.4V
-1 = Manual	-1 = No	-1 = JPEG	

Focus	Flash	Picture Quality (PQ)	Trial 1 (V)	Trial 2 (V)	Trial 3 (V)	Average (V)
-1	-1	-1	7.36	7.34	7.32	7.3400
-1	-1	1	7.35	7.37	7.31	7.3433
-1	1	-1	7.28	7.23	7.24	7.2500
-1	1	1	7.23	7.29	7.24	7.2533
1	-1	-1	7.36	7.3	7.35	7.3367
1	-1	1	7.25	7.28	7.26	7.2633
1	1	-1	7.19	7.25	7.23	7.2233
1	1	1	7.1	7.04	7.08	7.0733

	Focus	Flash	Picture Quality (PQ)	Focus*Flash	Flash*PQ	Focus*PQ	Focus*Flash*PQ
-1	7.2967	7.3208	7.2875	7.2758	7.2892	7.2700	7.2700
1	7.2242	7.2000	7.2333	7.2450	7.2317	7.2508	7.2508
Slope	0.0725	0.1208	0.0542	0.0308	0.0575	0.0192	0.0192

Appendix 2.2 – Canon M External Flash 90EX

At release of the camera, the Canon M had a completely new external flash (Canon 90EX) designed to match. It attaches via the hot shoe and is shown below.

Figure A.5: Canon M with Canon 90EX External Flash. Source: Photography Review, 2013 (http://rcdn.photographyreview.com/wp-content/uploads/2012/07/eos-m_flash.jpg)

Appendix 3.1 – Enlargement of Sankey Diagrams

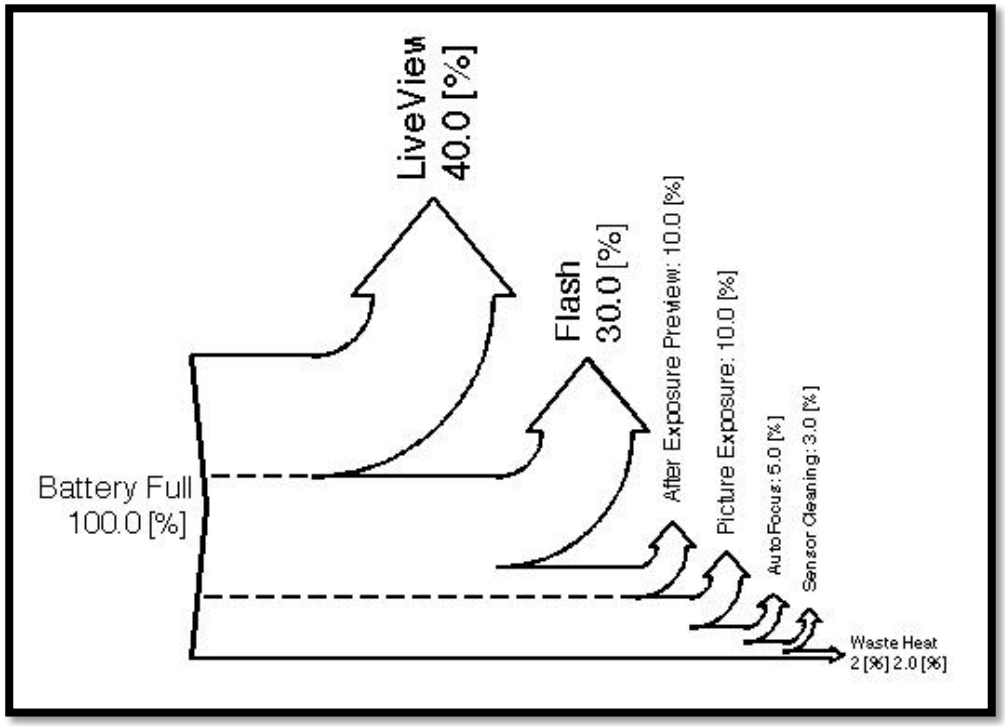

Figure A.6: Enlargement of the 60D Sankey Diagram

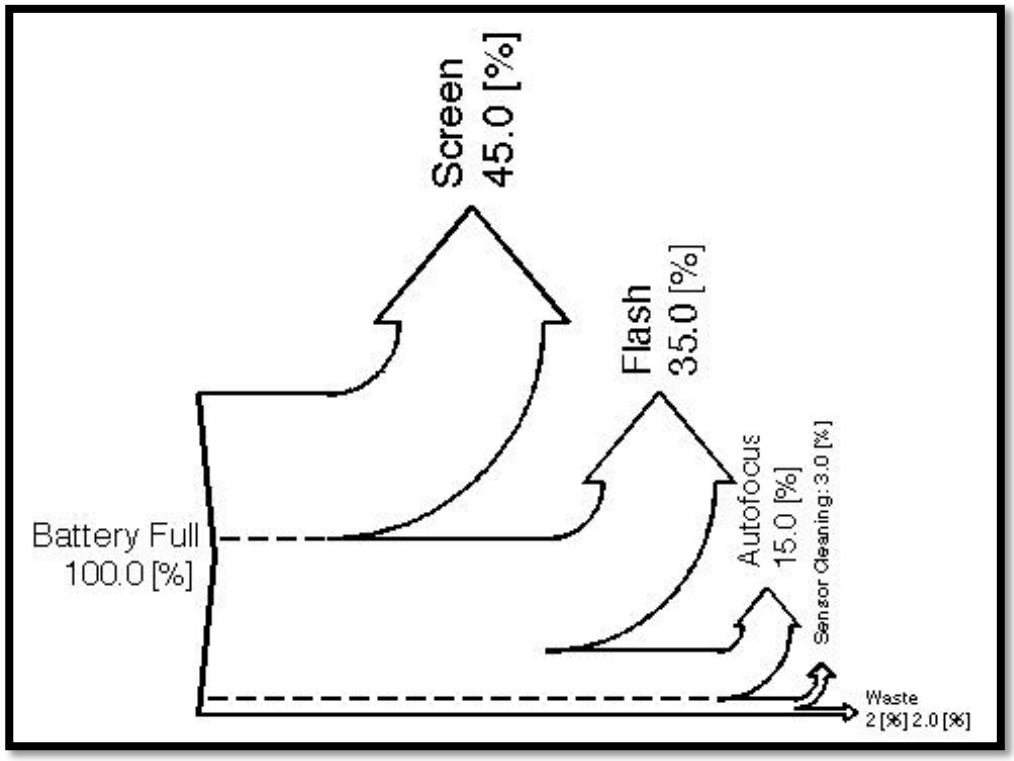

Figure A.7: Enlargement of the Canon M Sankey Diagram