protective cage. Although the coaxial main rotors does make the craft vulnerable to disturbances [8].

C. Tandem Rotors

A tandem rotorcraft is sometimes referred to as a dual rotor, as it consists of two blades to generate lift and to decrease disk loading and increase the payload lift capacity. In a tandem configuration the blades sit in the front and the rear of the craft, sometimes slightly overlapping. Tandems are often used in applications that require heavier loads than the traditional rotorcraft can effectively offer. In a tandem configuration the blades spin in opposite directions to counteract the other one's rotational torque. Pitch and Yaw control are readily available through manipulation of the rotor speeds, while roll control and left and right movements are not easily accomplished with this design [19]. Using two smaller blades also decreases the effects of interferences such as gusts on the craft, although a tandem helicopter has the problem of it's rear rotor being influenced by the wake of the front rotor[2] [12].

As described in (11) the thrust of the system increases slower than the electrical power input into the system. In a standard configuration, doubling the electrical power would only increase the thrust by a factor of ≈ 1.587. Where as doubling the amount of rotors being driven will double both the thrust and the electrical power. This gives the tandem arrangement the capability of lifting heavier loads with relatively low power consumption, as well as demonstrating low power consumption for hover and slow translatory flight. Having twin blades does increase the size of the craft, but the elimination of the tail rotor sees the size being similar to that of a classic helicopter. With no modifications the lack of roll control does limit the craft, although the drone will still be able to move left and right[3] by completing a yaw shift and then a forward movement. The control behind a tandem set up is by no means easy, but compared to it's traditional and co axial counterparts, adjustment of the rotor speeds can account for most of the desired control movements. When the two rotors have an overlap the mechanical couplings required to negate the chance of a collision can become difficult, however if the rotors do not overlap and each blade is coupled to it's own driving mechanism the need for complex mechanical designs is avoided.

D. Multirotor Designs

Drones have joined other remote controlled vehicles in the world of hobbyists. Of all the different designs, the multirotor is the most popular. Through discussions with drone designers and aerial photographers, the four rotor design is generally chosen due to it's incredible stability and manoeuvrability. Similar to the tandem, the quad has a very high disk loading ratio and thus can be used to lift heavy loads, there are even products that have ~~8~~ eight rotors to seriously increase the payload capability. This does however relate to a more power hungry system and a less efficient hover.

As shown in figure 6 [18], a quad rotor consists of two pairs of counter rotating propellers. Each shaft will be driven by it's own motor and unlike the flaps in a coaxial system, every motor in a quadcopter attributes to the lift vector. Having the freedom to control each blade independently gives the pilot advanced manoeuvrability, with minimal mechanical complexities. This also reduces the complexity of the control algorithms as six degrees of freedom can be obtained by simply adjusting the speed of the motors, and the multirotor can even rotate on the spot without any change in altitude [18]. Besides the poor hover efficiency, the biggest downside of the multirotor designs is their size and weight. Each blade requires a drive system and space to rotate without interference.

E. Tilt Rotors

A tilt rotor is a very sophisticated system that attempts to harness the benefits of both the fixed and rotor wing aircrafts. With the addition of a pivoting axis for each blade the craft has the forward flying speeds of a fixed wing craft while still being able to take off ~~an~~ and land vertically like a rotorcraft. The tilt rotor's major downfall is related to the required highly complex and intricate mechanical design [5].

VTOL applications require a larger blade to decrease the disk loading ratio, while in forward flight a smaller diameter blade is desired to increase the efficiency of propulsion. Hager [11] developed a telescopic system that transforms the blades to get the optimal benefits out of each configuration. These and other improvements have established the tilt rotor as a competitive design in the field of aeronautic transportation [5]. The main advantage of the VTOL system compared to other rotorcraft is the flight efficiency in longer flights.

Table 2 below is an example of a weighting matrix that tries to summarise the points discussed above, the example is for a drone used for aerial photography. The weighting values will be different for each application.

V. CONCLUSION

From the above discussion it can be seen that there is not a single configuration that is best suited for all applications. Instead each set up has it's own pros and cons which can