Make General Aviation Great Again: The Airplane

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction, Background, Significance

Flight is a power to be understood, and never underestimated. Aviation in the United States has been a vital part of every person's life whether or not they realize it, as it supports nearly 1.2 million jobs and a total of $246.8 billion in economic output[0]. The pilots, mechanics, manufacturers, technicians, air traffic controllers, and all members of the logistical processes of flight are part of a continent spanning network of thousands of airports, helipads, and airfields. Unfortunately, this number, as well as the state of general aviation as a whole, has been declining in the United States since its "golden age" in the 1970s and 1980s. This paper is my personal research done to try and prove this problem is real, discover the reasoning behind it, and present a methodology of how to fix this issue in a high-level analysis.

General Aviation, or GA, is the term used to describe anything to do with airplanes, airports, or air in the private sector (meaning this term excludes military and commercial flight). GA is currently a vital element in the fields of Emergency Organ Transplants, Emergency Hospital Transfer, Agricultural Spraying, Humanitarian Aid/Disaster Relief, Firefighting, Search and Rescue, Travel (especially in Alaska), and Law Enforcement, and the plethora of activities that come with an airport (skydiving, sightseeing/tours, airshows, etc.). Unfortunately, many of these GA airports have been disappearing over the years, as there were over 4500 in 1974[1], and less than 3000 in 2022[2]. A huge source of income for smaller towns and a huge source of identity and life for less populated communities have slowly degraded to the point of closure. Even knowledge of GA has slowly been forgotten, with the only time media referring to GA and pushing knowledge of its vital operations is to inform the general populace of another rare accident causing the death of a pilot (something that happens much more routinely in cars, with 6 million car accidents[3] vs ~1000 GA accidents per year[4]). GA as a whole has been on the decline since the 1970s, with participation in all related fields decreasing every year[5], and the price of even a 4-person GA aircraft increasing disproportionately every year[6]. A typical GA aircraft, the user-friendly Cessna 172, cost approximately $16,000 in 1975, less than an average Volvo 242 in the same year[7]. In 2023, the same airplane costs ~$400,000, and a similarly functioning modern car costs ~$40,000, an absurd difference. The manufacturing techniques, materials used, and overall design of GA aircraft has barely changed since the mid-1900s, unlike the automotive industry which has seen substantial modernization at every turn possible. As a former Aircraft Maintenance Technician, student glider pilot, and aerospace engineering student, I have seen areas where the industry could improve (considering most aircraft designs are from the 1950s still). The goal of my research is to analyze and present a framework whereby this price can be reduced.

Methodology

To adequately empower the reader with the proper knowledge and tools, I should preview the methods by which I intend to accomplish the goals of my research. Each preliminary topic will be derived from existing literature in which much research has already been done, beginning with literature about the current declining state of GA. The second literary analysis section will be on a study done on maintenance cost analysis, which gives a specific quantitative analysis into how to predict just how expensive over a lifetime average maintenance of GA aircraft will be. The third literary analysis section will cover a design environment created to give a big picture view of potential marketplace success of any given aircraft design, with a focus on transportation architecture, given current supply/demand conditions. One of the most important aspects of GA that has had more impact on the industry than any other is that of legal policies, of which will be my fourth topic of discussion. Finally, the last literature review will summarize the current US Government’s prediction and plans for the future of GA.

While these selections of literature do not cover the whole of planning, designing, and selling a new and affordable GA aircraft, a combination of the latter three topics (policy, maintenance cost prediction, and success prediction based on design parameters) will give the reader the tools they need to begin planning a new GA aircraft. The legal policies, both historically and in the modern day, will affect every aspect of GA more than other sectors, so they will be integrated separately from the next two sections. The manufacturing cost analysis provides potential for all costs of an aircraft (design, use, and maintenance), but only deeply studies maintenance. The success prediction environment only takes design parameters into consideration, but can be modified to incorporate other aspects such as maintenance, manufacturability, etc. My goal is then to merge these sections with the policy aspect and incorporate the Federal Aviation Administration's (FAA) plan to develop an overarching framework for designing the next generation of affordable GA aircraft.

Results - Literary Analysis

As all of this research was literary analysis, I will be going through each source and what they have indicated concerning the topic of this research: GA, its decline, and how to revitalize it. First, proof of the problem, that there really has been a decline in GA since the 1970s, and that problem warrants solving. In a modern aviation textbook, *Planning and Designing of Airports*, the problem is stated outright, “General aviation activity has experienced a decline in activity between 1980 and 2008,” as a preface to the world of GA, because it was such a concern in 2010 (Horonjeff, 2010).

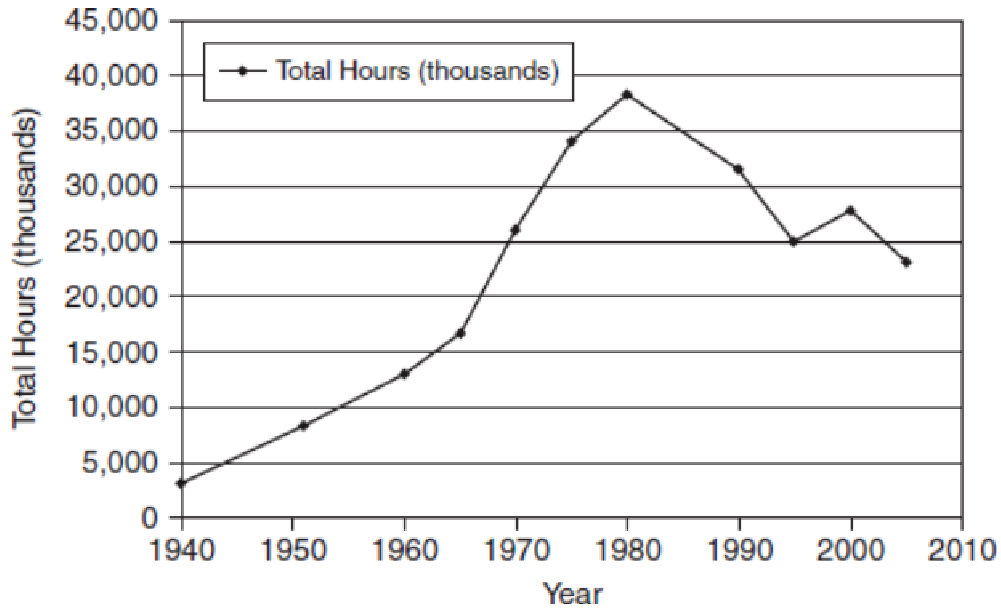

Figure 1: Total flight hours in GA aircraft in the United States, GA began largely after WWII, grew to great heights in the 1970s and 1980s, and has been in decline since (Horonjoff, 2010).

Unfortunately, this trend has continued, as there are now ~20,000 less aircraft in the US General Aviation fleet than in 2010, along with ~30,000 less pilots[8]. In a recent study into the modern state of infrastructure in the US, The American Society of Civil Engineers demonstrated an urgent worry about “crumbling roads and outdated airports,” fearing their degradation and loss would cost billions of dollars to the nation’s economy (Vock, 2019).

In beginning to look how to fix such a large issue, every aspect has to be carefully considered: legal policies, maintenance, manufacturing, advertisement, interest, support jobs available, current/old technologies in use, design, etc. I will begin with a summary of an in depth analysis of how to predict the maintenance cost of a GA aircraft. This study asserts that there are a huge array of factors influencing the potential cost of maintenance of a single aircraft:

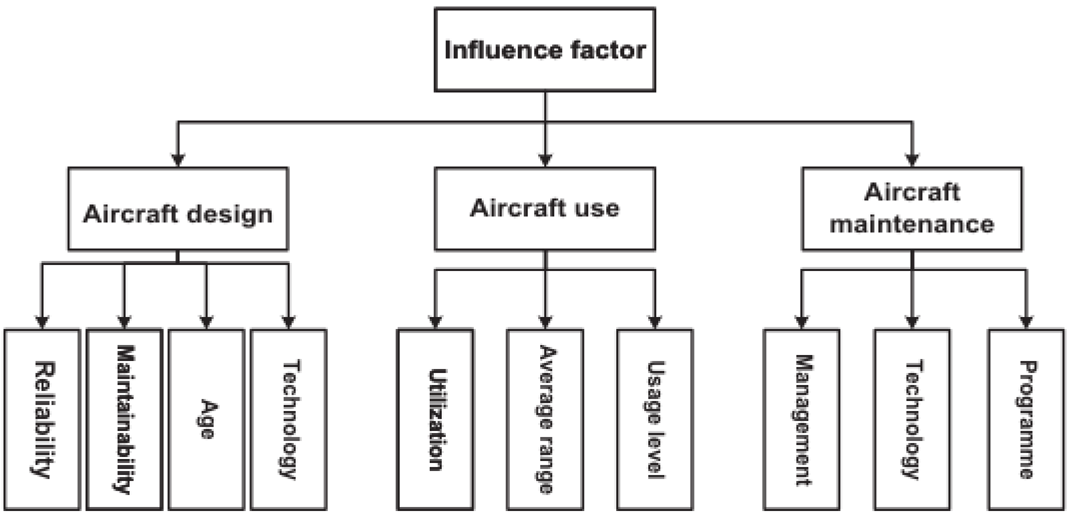

Figure 2: Factors that affect the cost of GA maintenance, each has a different level of influence.

The study suggests, and I agree, that a maintenance cost prediction should be an integral part of any design of a GA aircraft. The analysis method begins by identifying the current factors that go into the cost of a GA aircraft: direct costs such as labor, materials, and parts, indirect costs such as management and administrative work, planned and unplanned maintenance, etc. These costs all have levels of probability of occurring based on the influence factors in Figure X. For instance, some GA aircraft need a general inspection every 50 flight hours, a planned cost with predictable direct/indirect costs, but highly influenced by usage level of that aircraft in that region on average, rather than other factors. However, there are some airplanes that only need engine overhauls (larger inspections) every 2,000 flight hours, but due to age and technology of that aircraft, they are much more likely to need to replace several parts between each overhaul, making the scheduled overhaul slightly more redundant and unnecessary, driving maintenance costs higher overall. Through careful assigning of influence coefficients, and analysis of each cost and factor, the study arrived at a method that predicts (with 7%-20% accuracy) the cost of maintenance per year (denoted by the i) (all information sourced from Chen, 2023):

$$\begin{aligned} C_{i\_maintenance} &= C_{i\_direct} + C_{i\_indirect} = (1+\alpha)C_{i\_direct} \\ &= (1+\alpha)(1+\beta)C_{i\_planned} \\ &= (1+\alpha)(1+\beta)\sum_{j=1}^{8}(C_{j\_unit} + C_{j\_material})\frac{t_i}{T_j} \\ &= (1+\alpha)(1+\beta)\sum_{j=1}^{8}\left(c_{j\_labor}t_{j\_labor}p_j \right. \\ &\quad \left. + \sum_{k=1} c_{jk\_material}n_{jk\_material}\right)\frac{t_i}{T_j} \end{aligned}$$

Figure 3: Maintenance cost prediction equation, with each C being a cost, c being unit price of a consumable material, a and B being coefficients, t is flight time/labor time, T is maintenance intervals, p is the number of maintenance workers, and n is how many consumable materials.

The second study I wish to highlight is less focused on a specific area of the overall design of a GA aircraft and more focused on the overall transportation architecture of the GA aircraft (how it can get from the drawing board to the consumer). Similarly to the maintenance cost prediction analysis, this study begins by identifying the relevant factors that go into their analysis environment (aircraft design, supply of manufacturers/service providers and their factors determining market success, demand of consumers in renting vs owning GA aircraft, relevant socioeconomic factors, etc.). The study then quantitatively defines each factor and relates them as in the previous analysis. This study then presents the analysis environment backed by the quantitative analysis shown below:

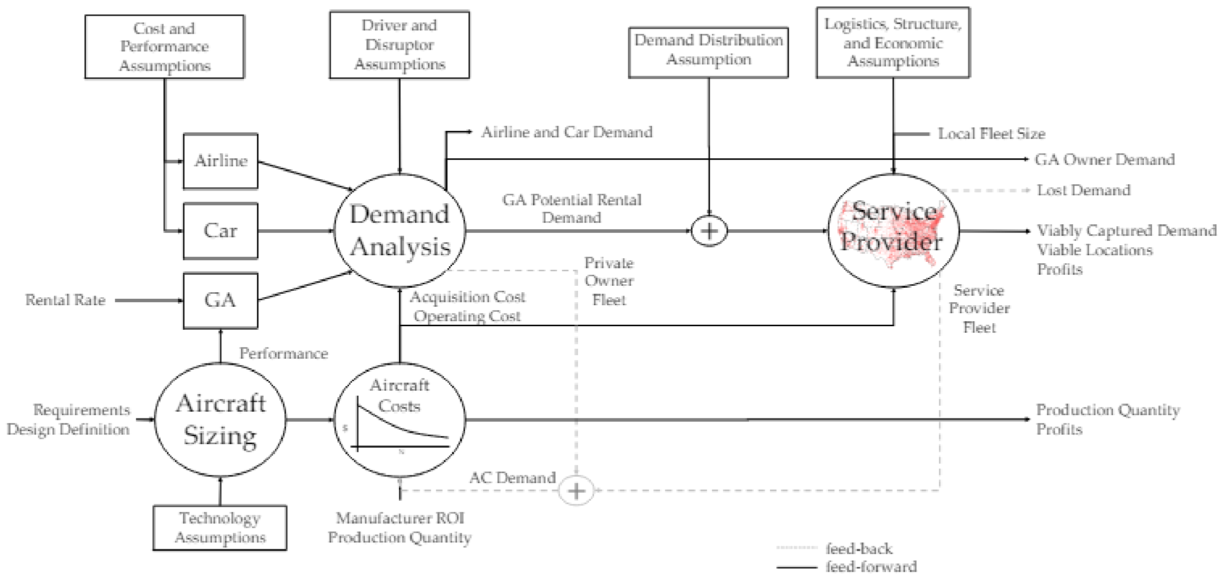

Figure 4: The blueprint for an analysis environment with several factors integrated, the goal of this analysis environment is to determine the viability of a service provider for a given design and can be adjusted to determine the viability of a design given the current state of GA (predict demand of that aircraft in the modern market).

The researchers then tested their program with the most common piston engine and jet engine GA aircraft, Cessna 182's and Cessna CJ3's respectively. They found their model (which took the design of the aircraft being different payloads and speeds) could accurately predict demand (as compared to real life statistics) within 5%. This data could then be used to further change the design of the aircraft to be faster, carry a lighter payload, etc. The study then integrated more and more variables (fuel efficiency, range, service provider profit, emerging technologies, etc.) to determine the reliability of the analysis model, and it performed within acceptable parameters, giving an accurate prediction of demand to profit ratio for the test aircraft's parameters (all information sourced from Won, 2012).

In 1994, the US Government attempted to revitalize the GA industry by means of the General Aviation Revitalization Act (GARA), which was largely unsuccessful in retrospect. The third literary analysis of this paper will attempt to explain what GARA was and how it impacted the GA industry in the short and long term. Much of the early decline of GA was caused by legal issues, mostly “product liability claims against manufacturers” (Stolzer, 1998). The study quotes that the “cost of maintaining the aircraft we fly has risen substantially due to product liability awards and the cost of their legal defense,” deducing that the cost of parts has risen and the availability of parts has plummeted due to a rise in these claims. The paper illustrates the necessity of these laws in ensuring the quality and safety of products released to the public, even though these laws increased the cost of aircraft in the 1980s by over 30%, led to the loss of over 65% of GA related jobs, and increased the cost of research and development to the point that to the date of the paper, little to no R&D has occurred in the industry since the late 1980s. Having worked on dozens of different aircraft myself, I can personally attest to the fact that we are still using designs and systems from the 1970s, and usually much before then. With the problem firmly identified, the paper explains GARA, which was the US Government's response to the problem. Basically, GARA protects manufacturers from product liability claims on parts/systems/designs over 18 years old (barring exceptions such as willful concealment of issues, special circumstances, and the like). Once GARA was enacted, the public began to have hope that GA was an industry worth participating in, and the industry began to pick up for a few short years. However, product liability claims continued, and the individuals pursuing legal action used the exceptions in their favor to circumvent GARA altogether, meaning that “the turnaround is based largely on the expectations of what GARA will do as opposed to what it has done.” Fortunately, the perceived success of GARA did give the GA industry enough of a boost to continue functioning, albeit still at a slow decline, and it shows that increasing optimism of the GA industry may be what the industry actually needs (all information sourced from Stolzer, 1998).

With older policy thoroughly discussed, I will now pull the reader to the present day and the future of GA, as predicted and planned by the US Government’s aviation sector, the FAA. In

2018, the FAA published a draft of an exploratory analysis of the state of GA by 2030 and beyond. They began by giving overarching forecasts in statistics as seen below:

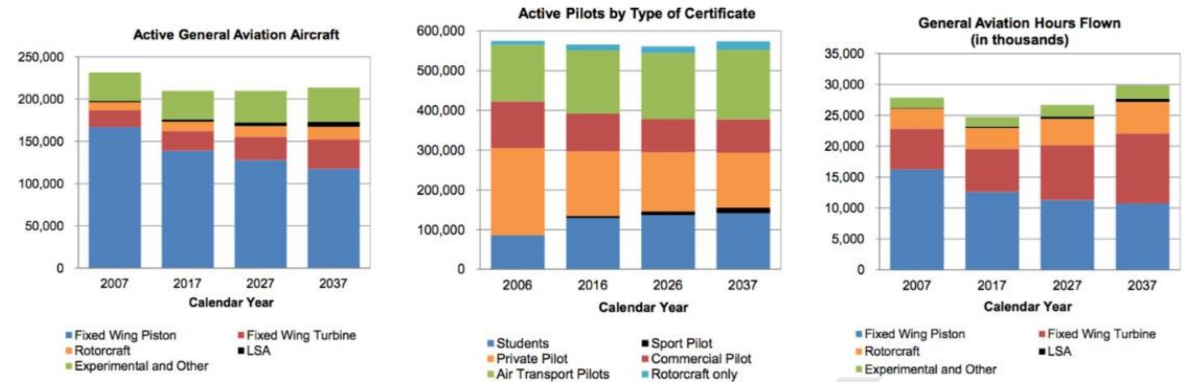

Figure 5: GA forecasts in fleet (left), pilots (middle) and flight hours (right), note the decline

With their projected increases displayed, they then discussed how these increases could happen by first identifying problem areas that need to be addressed (certification, management, infrastructure, and cost) and key changes that need to take place (urban mobility, new technologies, and automation). With the main topics identified, they listed all the secondary and tertiary topics that they predict will be addressed in the upcoming decades:

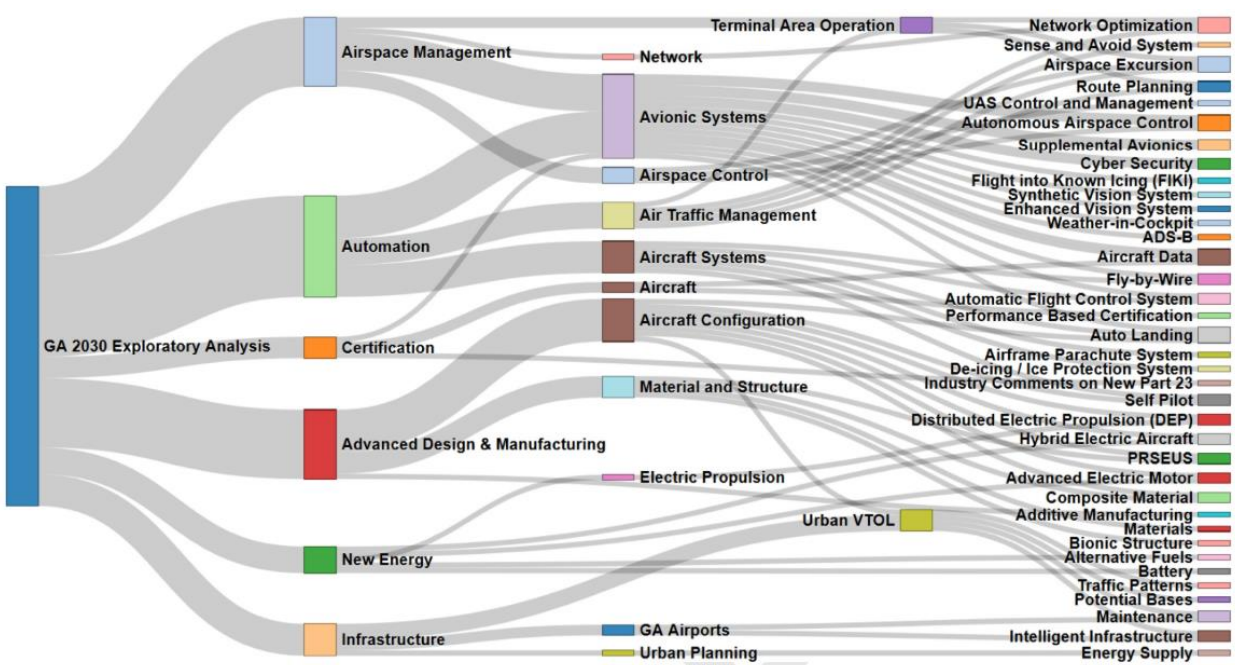

Figure 6: The 6 main topics, underlying secondary topics, and specific tertiary topics

They list dozens of new technologies that can assist in these endeavors, factors that influence the adoption of new technologies (cost, safety, privacy, etc.), and analyze their effect on the likelihood of success for new technologies in GA. They go through each system and subsystem of existing and experimental GA aircraft and how technologies can affect each of them. They overview the current status of each major country on GA throughout the world in 2017, and then begin to offer solutions to the problems identified earlier. In sourcing from various universities, private groups, government entities, and individuals about the research needed to be done to enlist more pilots, implement new technologies, decrease costs, and improve management and infrastructure, the final conclusions are complex, but it can be summarized with connectedness: the introduction of automation and virtual planning systems must be managed by many intelligent individuals to accommodate for the influx of aircraft from more efficient and appealing new technologies, and as these technologies grow and change, the airspace and airports must be ready to grow and change alongside them, with policy staying up to date. If interconnectedness is achieved, then every aspect of GA shown in Figure X will begin to flourish alongside one another at a manageable pace, attracting more consumers, producers, researchers, etc. to further continue the growth of GA (all information sourced from FAA, 2018).

Discussion of Results

With the problem and impact of the decline of GA proven and evaluated, we can conclude that the revitalization of the industry is of paramount importance. Each of the next four literary sources provide a useful perspective to be taken into consideration when designing a new GA airplane. The maintenance cost prediction method is quantitative and reliable, and can be used for maintenance or adjusted to predict manufacturing cost, research cost, and other costs. Using the success prediction method of the transportation architecture analysis paper, one can apply a variety of parameters from the modern state of the industry to periodically verify the viability of their aircraft designs. Understanding the policy impact of GARA offers a very valuable resource: optimism. If the US Government passes a law that at least appears to make GA a more appealing industry, then enthusiasm for the industry and investment in it will increase. There are always changes to be made concerning emerging technologies, so making them seem as attractive as possible (by lessening restrictions on their use or offering endorsements for their development) for the producers and consumers of the GA market is in the best interest of everyone involved. The FAA's 2030 plan/analysis provides a variety of potential research that needs to be done, jobs that need filled, and new career opportunities for individuals and organizations, all in all, their plan could work.

In order to truly push GA to revitalization, interconnectedness between all areas must be achieved. Updating aircraft systems or modernizing airports will not increase the number of pilots if the certification processes remain in a mid-19th century state. Providing an aircraft with a fuel-efficient carburetor similar to that of the Suzuki Alto L will not be an instant success if the speed/payload parameters show high likelihood of demand, among other necessities. The FAA seems to have a similar approach from their 2030 exploratory analysis of GA. Using their report and research suggestions as a guide, an individual can decide to contribute their skills (in unmanned systems, propulsion, etc.) to the industry. Advertisement of these fields of industry to the population of young college students and graduates would increase the number of workers in those areas. If a bill was passed that made it more favorable for GA aircraft manufacturers to exist, they would begin to hire more and produce more. If small communities were provided funding to revitalize their local airports, they would likely offer education and training in these refurbished airfields training the next generation of pilots. With younger pilots necessitates updated certification procedures, of which automation can highly progress. Automation in the manufacturing of new parts for old aircraft would necessitate further research and development in that area, pushing the current GA industry with "legacy" aircraft to new heights as well, allowing for cheaper parts, easier maintenance, standardized quality, an expansion of maintenance shops, and an inclination to grow the GA community. The revitalization of GA needs to be a continuous interconnected process, a series of loops, rather than a single line or step by step process, although in the future, the loops should be broken down into steps.

Conclusion

As this is my undergraduate thesis, I did not have the time or resources to fully investigate this high-level goal of revitalizing a multibillion-dollar industry, but this research was designed to be the baseline, the first step towards realizing that goal. The FAA is already well ahead of identifying the problems and presenting solutions, but I believe the materializing of the future of General Aviation lies in the future for all US industries: the American Youth, which is where the STS part of my research would come in, making a case for the mass introduction of youth ages 14-24 to General Aviation, as they would be the future pilots, researchers, mechanics, operators, planners, etc. For the next generation to be able to enter GA as an industry with any hope of payoff, the current generation needs to make the industry a desirable option, with plans, steps, laws, and funding in place ready to commence all whilst the education systems and local communities are introducing their youth to this niche, but vital industry. Although this paper covers the overarching goals and potential plans to revitalize GA, much specific research still needs to be done:

- Exact factors need to be identified and graded and an exact method for converting the maintenance cost analysis to other GA costs needs to be researched
- Exact policies to improve (at the very least) the optimism and hope in the GA industry need to be identified and planned to streamline legal processes especially aircraft and pilot certification

- Exact methods of attraction, advertising, and outreach of GA to individuals of every relevant age group and sector, relevant organizations of every size and scope, and even international partners need to be planned, as this will determine if the rest of the improvements even get noticed
- Exact plans for repair of older airports, modernization of manufacturing, increases in research and development of aircraft systems, implementation of new technologies, etc. need to be not only planned, but proposed to the leaders of the private and public sectors relating to aviation (FAA, DOT, manufacturers, AOPA, AIAA, etc.) for further optimization

Basically, this is an undertaking of enormous proportions, and requires the effort, enthusiasm, and intelligence of every relevant segment of society to make it happen. This is what I will be working on throughout my career as an Aerospace Engineer, in the maintenance, design, management, operations, or even as a pilot. It is my, and should be this nation’s, lifelong goal to make General Aviation great again.

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Footnotes

0: General Aviation News quoted a National Association of State Aviation Officials report giving the numbers stated in the text and positive commentary on the matter.

1: General Aviation Manufacturers Association, Statistical Data, 1976, table on page 21 reports 4,575 Public General Aviation (GA) Airports.

2: Federal Aviation Administration Report updated in 2022 states less than 3,000 Public GA Airports.

3: Bureau of Transportation Statistics with 2021 car crash data (6,102,936 per year).

4: Bureau of Transportation Statistics with 2021 GA crash data (1,157 per year).

5: Air Facts Journal shows several charts with relevant declines, especially showing the Private Pilot is becoming less common than the Airline Transport Pilot, and less common in general.

6: Forbes published in 2021 that the price of some Cessna 172s went from $12,500 in 1970 to some costing as low as $432,000 in 2021.

7: 1975-1980 Volvo 242 stats listed $18,900 as the highest sales price of the car.

8: The FAA keeps detailed statistics on General Aviation statuses over the years: https://www.faa.gov/sites/faa.gov/files/2023%20General%20Aviation%20%28Tables%2028%E2%80%9331%29.xlsx