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UNCERTAIN NEW TECHNOLOGIES – ECONOMICS OF GROUND EFFECT VEHICLE OPERATOR

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Abstract. New technologies and vehicle types have become available for transportation and logistics in the recent decade. One of the such is Ground Effect Vehicle (GEV), which in new reinvented form is using electric propulsion, new lighter materials and could be without onboard pilots. These could be used in coastal and archipelago types of areas, where distances are relatively short. In this research is introduced economic and business case evaluation of GEV in the context of Canary Islands. Aim is to build understanding from financial success of GEV. Simulation model incorporates number of uncertainties, like usage life-cycle of fleet, fleet investment cost, interest rates, lower cargo volume development in the early years and possibility for passenger transports. Analysis shows that success depends quite much on cargo pricing, and the interest of customers to pay premiums from faster delivery. Being operator of GEV offers possibility for profitability, but if most of uncertainties take place, then investments might increase too much and result on significant losses. Research provides added value on discipline development and better alternative on spreadsheet and cost focused models.

Keywords: ground effect vehicle (GEV), economics, new technologies, uncertainty, simulation.

JEL Classification: C6, D8, M2, 03, L9.

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1. Introduction

In the recent decade we have witnessed numerous new vehicles and devices introduced in transportation and logistics, mostly based on drone technology. These are typically much smaller in size than, e.g. delivery vans or conventional airplanes, but have developed in performance within short period of time, and many companies (Yowtak et al., 2020) and countries (Chi et al., 2023) are having implementation and usage cases at the agenda. Typically, these new vehicles are unmanned, and software as well as sensor controlled, while control room only takes care of the overall progress (Laghari et al., 2023). In addition to drones, Ground Effect Vehicles (GEV) have reborn in this new development. These are using ground effect of sea surface to gain travel efficiency, and will fly few meters above sea level. GEVs were earlier used for very heavy item transport (like military; Nebylov & Nebylov, 2021), and combining it with some passengers (Paek, 2006). However, new coming of GEV is based on much lighter structures, and planes, which could carry few passengers (typically up to 10) and cargo (den Breejen, 2018). In addition, operating range of new type of GEVs is shorter (Papadopoulos et al., 2022) and overall load on plane is also an issue together with stability (Amir et al., 2016). These require attention in order that GEVs could be commercially viable. In new GEVs propulsion is typically electric (Papadopoulos et al., 2022). There still exist research gap to be filled regarding the use of these new vehicles (drones and GEVs), and their economic suitability to real-life transportation and logistics chains. This research aims to address situation and build understanding from profitability and cash flow of GEVs using interactive simulation model.

In commercial evaluation of new vehicles there exist number of issues to be taken into account. Typically, evaluations are only based on costs, where different cost items of new vehicles are incorporated in the decision-making (like fuels/electricity use and cost of it, labour need, investment amounts, interest rates, overhead, loading-unloading costs, facilities needed etc.). However, as these new vehicles are still evolving and developing, their performance is typically lower than mainstream used vehicles (or legislation prevents their full use; Lanzalonga et al., 2023). Therefore, revenue needs to be incorporated in these economic evaluation models, and this will concern both uncertain factors volume development and freight prices. New technologies hold also other uncertainties, like how long time new vehicles could be used in operations (technical, but also performance issue as newer vehicles might have much better performance), and what kind of ramp-up period new services are having among potential customers (corresponding to lower demand and use). For example, Lanzalonga et al. (2023) studied potential drone use in Venice, Italy for pharmaceutical distribution from pharmacies to homes. This is typical example of disruptive mobility entry to markets – some special area and product group is often the most convenient for disruptive innovation (Christensen et al., 2018; Lanzalonga et al., 2023). In this background, research question of this study is as follows: "What kind of revenue streams and levels result in profitable GEV operations?" In this research work GEV is placed to serve certain predetermined route, similarly to sea vessels. For this research project, we have been interested from Canary Islands (Spain), where main cargo and population hubs could be as such. Research novelty lies in its clear and determined setting as well as applying interactive simulation model first time with financial evaluation of GEV.

This research is structured as follows: In Section 2 is reviewed different research works of building profitability and cash flow simulations from new companies, products and services. Thereafter in Section 3 is introduced GEV simulation model and its assumptions. Built simulation model contains considerable interactive features, which give valuable insights for its users. In Section 4 is analyzed, how example outcomes and different reporting forms are produced by simulation model. Focus is kept in the analysis of profitable enough operations through revenue streams. Used interactive simulation model enables also to use Monte Carlo simulation in the deeper further analysis. Research is concluded and discussed in the final Section 5. Further research avenues are also being proposed.

2. Literature review: simulation models for profitability and cash flow

Simulations have been found out to be a suitable approach when assessing financial feasibility of investments and business opportunities with significant uncertainty. Table 1 provides an overview of recent articles from years 2015–2024 found to be relevant on the topic of utilizing simulation, when analyzing profitability and cash flow characteristics of investment projects (based on Scopus and Web of Science/Clarivate database search). In Table 1 research works are sorted in descending fashion by the number of citations. Regarding analysis on introduction of new technologies, simulation models have been applied e.g., in studying profitability of autonomous vessel development (Yaniv & Beck, 2024), energy storage (Lee et al., 2022; Yaniv & Beck, 2024; Wessel et al., 2020), manufacturing strategy or operations planning (Murphy et al., 2020; Pellegrino et al., 2024; Yoo et al., 2018), and chemicals production processes (Junqueira et al., 2018). Likewise, simulations have been used to analyze business cases in the more established settings, like mining projects (Montiel & Dimitrakopoulos, 2015; Kamel et al., 2023), agriculture (Shortall et al., 2016; Cann et al., 2020; Monjardino et al., 2022), forestry (Chudy et al., 2020; Scudder et al., 2019), energy (Aquila et al., 2017; Ghoddusi, 2017), and finance (Grundke & Kühn, 2020).

Multiple simulation methods, suitable for different applications and end-user needs, have been utilized in recent research. Regarding analysis on profitability and financial feasibility of different investment opportunities, Monte Carlo Simulation (MCS) is among the most widely used, with several software tools available to enable its application (Aquila et al., 2017; Ghoddusi, 2017; Chudy et al., 2020; Kamel et al., 2023; Lee et al., 2022; Scudder et al., 2019; Wessel et al., 2020; Pellegrino et al., 2024; Monjardino et al., 2022; Yoo et al., 2018). Other simulation methods used for this purpose include Discrete Event Simulation (DES) (Murphy et al., 2020; Ivanov, 2024), Dynamic Programming (DP) (Yaniv & Beck, 2024), and Stakeholder Value Network (SVN) analysis (Nakashima et al., 2023). In addition, proprietary simulation tools developed for a specific purpose are also quite common (i.e., Montiel & Dimitrakopoulos, 2015; Junqueira et al., 2018; Shortall et al., 2016).

Regarding Key Performance Indicators (KPI) and other metrics used to assess the feasibility of an investment case or to compare alternatives, Net Present Value (NPV) is the most common (Montiel & Dimitrakopoulos, 2015; Aquila et al., 2017; Cann et al., 2020; Kamel et al., 2023; Lee et al., 2022; Scudder et al., 2019; Wessel et al., 2020; Pellegrino et al., 2024; Monjardino et al., 2022; Yoo et al., 2018). Another commonly used approach is to study the cash flow characteristics of the project of interest, not taking in account the time value of money via discounting (Shortall et al., 2016; Murphy et al., 2020; Scudder et al., 2019; Ivanov, 2024). Other KPIs used include Return On Investment (ROI) (Shortall et al., 2016; Nakashima et al., 2023), Internal Rate of Return (IRR) (Chudy et al., 2020; Kamel et al., 2023), Profit (Shortall et al., 2016; Ghoddusi, 2017), Payback Time (PP) (Kamel et al., 2023), and Discounted Payback Time (DPP) (Lee et al., 2022). As is common in financial analysis, both in literature and in practice, more than one KPI is often utilized when assessing investments.

There exist only two transportation classified simulation studies in Table 1. Ivanov (2024) is using simulation to examine cash flow dynamics in the face of disruptions within supply chain context. This research is analyzing one year period using daily observation frequency. Another transportation research is that of Nakashima et al. (2023). This research is strategic in nature, and concerns long-term changes needed to make autonomous vessels financially and technically possible. It is interesting to note that neither one of these studies concerns drones or similar new technical solutions to transports. There is clearly a need for simulation models and analyses from these as their adaptation and use has increased so much in the previous decade. This gives justification for this research work and its developed interactive simulation model.

3. Interactive simulation model: ground effect vehicle

Built simulation model could be divided into two different parts: (1) revenue streams and (2) cost/investment items. As could be detected from Figure 1, revenue streams and their sub-items are on left-side of figure, while cost/investments are in the right-side. All affecting parameters and elements are brought together in the bottom of Figure 1, where there exist revenue and costs flows of profit-loss, and then separately cash flows – inflows are cumulative revenues and outflows cumulative payments. Main difference between profit-loss and cash flow is the made investment for ground effect vehicle (together with its charging infrastructure). In the profit-loss calculations this investment is depreciated with stated usage life-cycle of the fleet (in equal amounts), while in cash flow it is registered as a payment in the very beginning of the simulation run.

As there are number of uncertainties with new technologies, these very tried to be incorporated in the simulation model. One of them is the usage life-cycle of the fleet. This could vary substantially from 10 to 30 years. Simulation model itself was defined to have 30 years of simulation period (with annual time steps). However, as model was built to be interactive, and having this possibility for different usage period from 10 to 30 years (please visit for details, InsightMaker, 2024). Therefore, usage life-cycle of fleet was added to simulation model, and it has connections to depreciation programme of made investment, and to all main revenue, cost and cash flows of the model. In investment depreciation model it defines in equation to how many years investment will be depreciated, and in other it is time limit to how many years revenue, cost, and cash flow data will be recorded in the model. So, even if simulation model is having 30 years of simulation run,

Table 1. Overview of literature review reference articles

	Publication	Industry	Simulation method used	KPI(s)	Citations*
1	Montiel and Dimitrakopoulos (2015)	Mining	Stochastic mine orebody simulation**, Perturbation optimization algorithm**	NPV	97
2	Aquila et al. (2017)	Energy	Monte Carlo Simulation	NPV	45
3	Junqueira et al. (2018)	Chemicals	Industrial chemical production processes simulation**	SPCi (Specific Production Cost indicator), ECI (Eco-efficiency Comparison Index)	36
4	Shortall et al. (2016)	Agriculture	Moorepark Dairy Systems Model (MDSM)**	Profit, Cash flow, ROI	30
5	Cann et al. (2020)	Agriculture	Agricultural Production Systems sIMulator (APSIM)**	NPV, Cash flow	28
6	Wessel et al. (2020)	Energy	Monte Carlo Simulation	NPV	28
7	Murphy et al. (2020)	Manufacturing	Discrete Event Simulation	Cash flow	26
8	Ghoddusi (2017)	Energy	Monte Carlo Simulation, Copula Model	Profit	15
9	Grundke and Kühn (2020)	Finance	Bank balance sheet development simulation**	Equity return, Balance sheet growth, Probability of illiquidity, Future cash flow	14
10	Chudy et al. (2020)	Forestry	Monte Carlo Simulation	IRR	14
11	Kamel et al. (2023)	Mining	Monte Carlo Simulation, Binomial Decision Tree	NPV, IRR, PP	13
12	Pellegrino et al. (2024)	Manufacturing	Monte Carlo Simulation	NPV	13
13	Monjardino et al. (2022)	Agriculture	Monte Carlo Simulation	NPV	11
14	Ivanov (2024)	Transportation	Discrete Event Simulation	Cash flow	10
15	Lee et al. (2022)	Energy	Monte Carlo Simulation	NPV, DPP	9
16	Yaniv and Beck (2024)	Energy	Dynamic Programming	Cash flow	8
17	Scudder et al. (2019)	Forestry	Monte Carlo Simulation	NPV	7
18	Yoo et al. (2018)	Manufacturing	Monte Carlo Simulation	NPV	6
19	Nakashima et al. (2023)	Transportation	Stakeholder Value Network analysis	Introduction time for fully autonomous ship, ROI, Number of possible maritime accidents, Number of seafarers	2

Note: *Number of citations per article based on data from Scopus as of 23 January 2025; **Proprietary simulation method or tool.

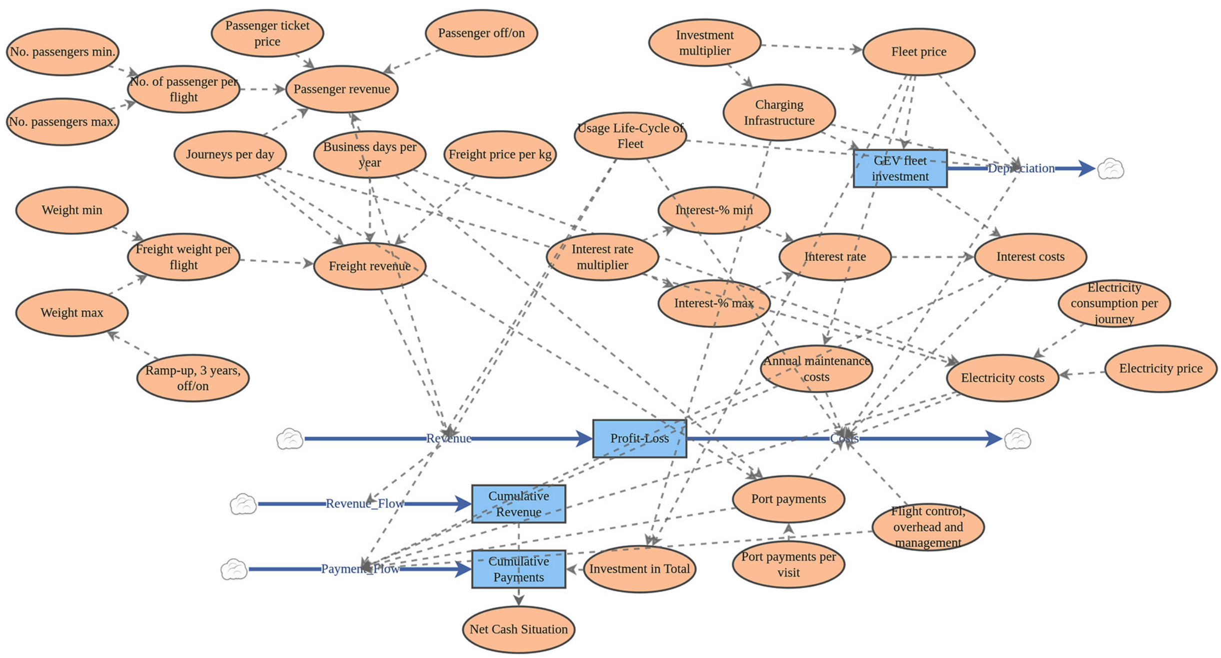

Figure 1. Ground Effect Vehicle (Airship) simulation model (source: interactive simulation model; InsightMaker, 2024)

user may alter usage life-cycle of fleet, and actually alter the simulation length. All users of simulation model have also been enabled to copy/clone simulation model from its website to replicate, and possibly to modify this simulation model for their own research purposes (InsightMaker, 2024).

For other uncertainties in the model, model incorporates ramp-up period in freight services. This is modelled in a way that maximum freight amount is limited to 2000 kg per flight in the three first years, while in following years (and without ramp-up period at all) it is 4000 kg per flight. Ramp-up could be caused in real-life by number of reasons, like technical issues with higher loads in the beginning of operations, and/or lack of demand for given freight services. Freight transported in each flight in the model is based on random uniform function with minimum (1000 kg) and maximum (2000 or 4000 kg) values.

It is uncertain at the moment whether ground effect vehicles using electrical propulsion could be used only for freight transports, but could they be serving both freight and passenger transports. This was implemented in the interactive simulation model by similar way as freight transports – passenger amounts vary based on random uniform distribution with stated minimum (two passengers) and maximum (10 passengers) values. These are then incorporated in the revenue model, if user selects passenger transports on within the model.

Built simulation model is based on configuration that ground effect vehicle serves particular two node route (from A to B and then back to A), and this is served for selected amount of days in a year (250 days per year as pre-selected in the model), and selected amount of journeys per day (from one node to another, pre-selected for five journeys). These values are used in the simulation model to convert average freight and passenger amounts to revenues. Equations also incorporate freight price (per kg) and passenger ticket price. These prices could be altered in interactive model, but freight is set to 0.5 EUR per kg and passenger ticket to 25 EUR. Our research project and simulation model being built was focusing on Canary Islands, and this hypothetical two node route could be between main hubs of islands (having both cargo and passenger potential), like those of Gran Canaria (Agaete and Las Palmas) and Tenerife (Santa Cruz and Los Cristianos).

Model also incorporates sliders for uncertainties of investment amount – how many times investment could cost more than what was initially budgeted (investment multiplier). Similarly, interest rates for used capital of investments contains selection for higher rates (interest rate multiplier). In initial setting investment amount is set in the model for 2.1 mill. EUR and interest rates vary with random uniform function from minimum of 3% to maximum of 10%.

In cost side model also incorporates fuel costs, in this case electricity use of GEV with electricity price of 0.3 EUR per kWh (this is based on route, which is around 100 km in distance). Port payments (200 EUR per visit) are paid based on visit activity during the year. Flight control, overhead and management are lump-sum of 300,000 EUR per year (contains also costs incurred from sales and booking). Do note that onboard of evaluated GEV there does not exist any pilots (being autonomous), and there is just flight control for it. Annual maintenance costs of used fleet is set to be 6% from fleet acquisition price.

Used parameters and equations of simulation model are reported in the following. First is given revenue based parameters and equations (Equations (1)–(16)), and then costs (Equations (17)–(33)), and finally overall stock-flow model parameters and equations concerning profit-loss, revenue and payments as well as cash flow situation (Equations (34)–(40)).

No. passengers min. = 2; (1)

No. passengers max. = 10; (2)

No. of passenger per flight = Round(Rand([No. passengers min.], [No. passengers max.])); (3)

Passenger ticket price = 25; (4)

Journeys per day = 5; (5)

Business days per year = 250; (6)

Passenger off/on = 0; (7)

Passenger revenue = IfThenElse([Passenger off/on]=1, [No. of passenger per flight]*[Journeys per day]*[Business days per year]*[Passenger ticket price], 0); (8)

Weight min. = 1000; (9)

Ramp–up, 3 years, off/on = 1; (10)

Weight max. = IfThenElse([Ramp–up, 3 years, off/on]=1, IfThenElse(Years()>2, 4000, 2000), 4000); (11)

Freight weight per flight = Rand([Weight min], [Weight max]); (12)

Freight price per kg = 0.5; (13)

Freight revenue = [Journeys per day]*[Business days per year]*[Freight price per kg]*[Freight weight per flight]; (14)

Usage Life–Cycle of Fleet = 20; (15)

Revenue = IfThenElse(Years()<[Usage Life–Cycle of Fleet], [Freight revenue]+[Passenger revenue],0); (16)

Investment multiplier = 1; (17)

Charging Infrastructure = 100000*[Investment multiplier]; (18)

Fleet price = 2000000*[Investment multiplier]; (19)

GEV fleet investment = [Fleet price]+[Charging Infrastructure]; (20)

Depreciation = ([Fleet price]+[Charging Infrastructure])/[Usage Life–Cycle of Fleet]; (21)

Interest rate multiplier = 1; (22)

Interest–% min. = 0.03*[Interest rate multiplier]; (23)

Interest–% max. = 0.1*[Interest rate multiplier]; (24)

Interest rate = Rand([Interest–% min], [Interest–% max]); (25)

Interest costs = [GEV fleet investment]*[Interest rate]; (26)

Annual maintenance costs = 0.06*[Fleet price]; (27)

Electricity consumption per journey = 540; (28)

Electricity price = 0.3; (29)

Electricity costs = [Electricity consumption per journey]*[Electricity price]*[Journeys per day]*[Business days per year]; (30)

Port payments per visit = 200; (31)

Port payments = [Port payments per visit]*[Business days per year]*[Journeys per day]; (32)

Costs = IfThenElse(Years()<[Usage Life–Cycle of Fleet], [Port payments]+[Interest costs]+[Depreciation]+[Annual maintenance costs]+[Electricity costs]+[Flight control, overhead and management], 0); (33)

Profit–Loss = [Revenue]–[Costs]; (34)

Revenue_Flow = [Revenue]; (35)

Cumulative Revenue = [Revenue_Flow]; (36)

Payment_Flow = IfThenElse(Years()<[Usage Life–Cycle of Fleet], [Port payments]+[Annual maintenance costs]+[Electricity costs]+[Interest costs]+[Flight control, overhead and management], 0); (37)

Investment in Total = [Fleet price]+[Charging Infrastructure]; (38)

Cumulative Payments = [Payment_Flow]+[Investment in Total]; (39)

Net Cash Situation = [Cumulative Revenue]–[Cumulative Payments]. (40)

4. Example outcomes and reporting forms

As interactive simulation model contains so many user defined parameters, its outcomes are vast. In the following these are illustrated with some examples. In general, costs of operations of GEV are rather fixed, and being around 1 million EUR (see Figure 2). This of course has some higher values in the beginning of simulation period as depreciation and interest rates take much higher amounts from overall costs. As Figure 2 illustrates, key for profitability is the revenue gathered during each year. Ramp-up period is selected as “on” within Figure 2 simulation run, and it will lead to the situation, where revenues stay below costs for first three years in the simulation results. So, it is rather vital to have freight capability and demand for freight services from the very beginning.

Payback period of given same configuration is shown in Figure 3. Within six years made investment will pay itself back. In the end of given 15 year usage life-cycle of fleet, cash flow is positive, but only by around 6–7 mill. EUR.

This is accomplished with rather high freight rate of 0.5 EUR per kg. So, based on these results, it seems that GEV is mostly suited for marginal and specific cargo groups, which are willing to pay from fast transportation service. Think about semi-trailer truck having total forty feet container of weight of 15 tons. This would be having cost of 7500 EUR to transport for 100 km. It is more than what container would cost to transport from Europe to China (even in a little bit un-normal times).

Figure 2. Example outcome and output report of simulation from revenues and costs model as ramp-up period is on, but no passengers on board (0.5 EUR per kg freight rate and 15 years of usage life-cycle of fleet)

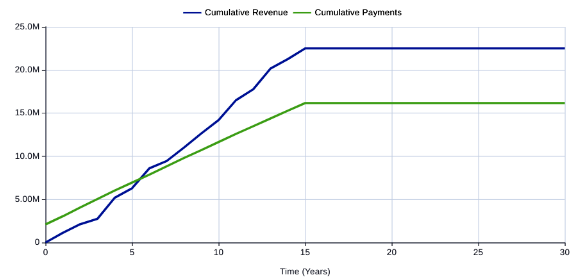

Figure 3. Example outcome and output report of simulation model from cash flow elements as ramp-up period is on, but no passengers on board (0.5 EUR per kg freight rate and 15 years of usage life-cycle of fleet)

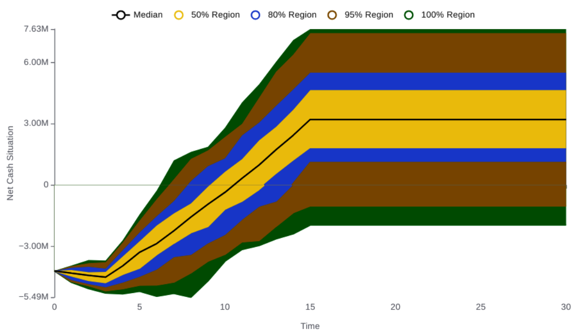

Figure 4. Net cash situation with Monte Carlo simulation (100 runs) as both ramp-up and passenger options are on, but investments costs are double to original planned amount (0.5 EUR per kg freight rate, 25 EUR per passenger ticket and 15 years of usage life-cycle of fleet)

As new technologies contain a lot of uncertainty, and many things could go wrong, and within undesired direction, it is worthwhile to analyze, how much possibly GEV operator in route might need funding to continue operations for the entire period. In Figure 4 is shown extensions to earlier examples, where ramp-up period is "on", but GEV is also able to serve passengers. However, investment costs are double compared to what they were estimated in the initial model. In worst situations net cash flow is at –5.5 mill. EUR. In 15 years usage period cash flows have anyway possibility to recover in positive territory, but they may remain negative as well. Cure for this situation would be to increase prices of services (particularly cargo), however, it is uncertain whether customers can tolerate cargo pricing of 0.6 to 0.7 EUR per kg. Similar situation, but even worse, is shown in Figure 5. Investment costs are triple to original amount, and interest rates are double. Ramp-up period is "on", but no passengers are being transported. Net cash flow situation will remain in negative territory for the entire 20 year usage period. In worst situation operator may need to have as much as 15 mill. EUR to remain in the business. Way out of this situation is also freight rate increase, but in this situation it should increase up to 0.8–0.9 EUR per kg.

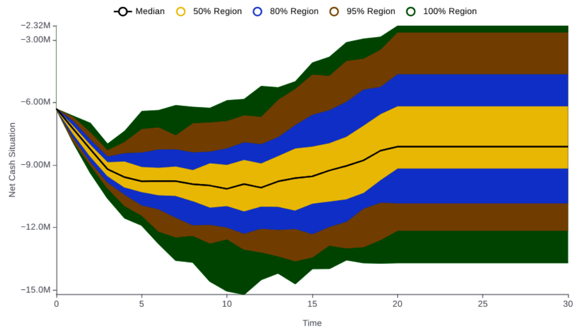

Figure 5. Net cash situation with Monte Carlo simulation (100 runs) as both ramp-up option is on (passengers off), but investments costs are triple to original planned amount and interest rates double (0.5 EUR per kg freight rate, and 20 years of usage life-cycle of fleet)

Passenger ticket prices could also be used to tackle negative cash position in Figures 4 and 5. However, this would mean substantially higher ticket prices. In Figure 4 configuration passenger ticket should be priced as double compared to base case (new price would then be 50 EUR). In Figure 5 situation passenger transportation option was off, but if that would be enabled, then ticket prices need to reach level of 100 EUR in order that cash flow direction changes and is most probably positive in the end of the simulation period (20 years usage of fleet).

Complexity of profitability and cash flow are well illustrated in simulation trials. In the very beginning, single run simulation experiment showed proper (or somehow acceptable) profitability and cash flow as well as payback time (Figures 2 and 3). It is of course challenging to have ramp-up period in the model and then later on within full freight transportation volumes having annual fluctuation (Figure 2), but over 15 years of usage life-cycle these could be tolerated. However, if investment costs are not met with full production and commercialized GEV, then even longer usage life-cycle of GEV together with passenger transportation do not change bleak loss rate (Figure 5). In both of the cases (Figures 4 and 5) substantial increases on freight rates and passenger ticket prices are needed to assure profitability and payback time. These also represent significant threats for business success of GEV as demand is always a function of price.

5. Concluding discussion

Similarly to previous literature on the topic, research introduced in this article applies simulation to address the significant uncertainty of introducing new technology in commercial operations. Monte Carlo simulation is a commonly used method to analyze different types of investment projects, which contain several input variables with uncertainty (e.g., Aquila et al., 2017; Ghoddusi, 2017; Chudy et al., 2020; Kamel et al., 2023; Lee et al., 2022; Scudder et al., 2019; Wessel et al., 2020; Pellegrino et al., 2024; Monjardino et al., 2022; Yoo et al., 2018). It was therefore selected to be used in this research for GEV transportation business case analysis. A development introduced in this research in comparison to previous literature is the software tool used to build and run the simulation, and analyze its results. In previous research spreadsheet-based software (Paek, 2006; den Breejen, 2018), such as Excel with suitable add-ons, is mainly used to conduct cost estimations with some sensitivity analysis (and possibly simulation). In this research a system dynamics based tool was selected instead. This provides several benefits over spreadsheet-based alternatives. First, constructing the simulation model with graphical interface (see Figure 1) is easier and faster than relying on complex formulas with multiple cell references required when using spreadsheet software. This also allows any possible errors in the model to be checked and detected more effectively when simulation model is being developed. Secondly, the simulation model can be shared with GEV transportation business case stakeholders, who can then conduct their own simulation runs with different settings and variable values. This allows the stakeholders to independently study outcomes of different scenarios with very short briefing. Sharing and low barrier to use with interaction have already been identified as a very useful features as this simulation model has been part of a larger European wide research project. As the InsightMaker simulation platform used in this research is an open-source, free to use software accessed via Internet browser and requiring no registrations, it provides very low barrier to entry to practically anyone. Third, the simulation model developed for this research is open to be copied. This allows it to be further developed or utilized as a basis for other simulation models, whether for scientific, business, or other purposes.

New lighter structure vehicles are starting to enter commercial markets, and disruptive mobility solutions need to find their own space from freight and passenger segments. Interactive simulation model of this research work examined the feasibility of GEV in given regular route, where mainly freight segment is being served. However, in simulation model it was given as optional that some smaller amount of passengers could also be served. Built simulation model contains numerous parameters, which user may alter. These portray the uncertainty of GEV implementation. Simulation results illustrated well that freight rate level needs to be at high level, whatever is the situation (implementation proceeds as planned or with realized risks). Challenge in GEV implementation is varying revenue, which in the model is based on freight volumes. Cost structure itself is rather fixed, even if interest rates contain uncertainty. It is understandable that uncertainty of revenue, profits and cash flow could be tackled with additional revenue streams. Therefore, passenger transports is good additional source of revenue, however, ticket prices need to be medium to high that it holds real relevance.

Based on simulation model, it is vital that investments in GEV do stay within budget. As illustrated in the results, cash flows may drop to significantly low levels, if investments costs are tripled. In addition, this challenging cash flow situation of course contained doubled interest rates. Of course, investments to vehicles in any type of transport business play critical role (like shipping), but in lighter disrupting mobility solutions it could have been assumed not to be so significant. However, in simulation model it is assumed that annual maintenance costs are driven by initial investment costs. So, total cost of GEV fleet is its annual depreciation, interests paid and maintenance. Higher than planned investment costs impacts these all. This also represents limitation of proposed simulation model as its results are investment centric. As GEV is still under development and not commerzialized, its total investment costs hold certain amount of uncertainty, and unknown operational cost implications.

As further research in simulation modelling area, we would like to expand this interactive simulation model also to drones. This is of course different setting as drones do not serve predetermined route, but point to point system with numerous different destinations with huge amount of transactions and low freight rates. Investments are also different as number of needed drones is high. In addition, seasons and weather pose challenge for drone operations, which should also be incorporated within model.

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