FUNDAMENTALS OF STATISTICS

PROBABILITY DISTRIBUTIONS, RISK ASSESSMENT, AND DECISION-MAKING UNDER UNCERTAINTY

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Executive Summary

In this assignment, students will use discrete and continuous probability models for making decisions about a hypothetical German tour operator. It combines officially reported German tourism activity with an operational risk scenario, built on an Excel-based platform. The Binomial model is used for invoice defaults, the Poisson model is used for customer enquiries per hour, the Normal model is for capacity pressure and a probability weighted decision tree for fixed vs flexible tour capacity. According to the final Destatis data, in 2025, Germany experienced 497.4 million overnight stays in accommodation facilities, which is a national aggregate and therefore not directly comparable with the number of overnight stays of the hypothetical operator (Federal Statistical Office [Destatis], 2026).

The estimated probability for 30 invoices to default is 33.9%, 15.6% for 16 or more enquiries during a peak hour, and 9.1% for demand in excess of 100 tour places. The expected profit is higher for fixed capacity (€1750) than for flexible capacity (€1375) but the downside risk is significantly lower for flexible capacity. A recommendation is to keep flexible capacity, and enhance data collection, model validation and risk governance. Useful forecasts, as actual case evidence in Munich Re, JPMorgan, and Long-Term Capital Management shows, can't be just mathematically correct but require management control as well.

Introduction

Tourism businesses sign contracts with promises before they can be certain of profits. Although bookings, cancellations and failure to pay haven't been known, seats for accreditation, coach cost or temporary staff must be booked or reserved. Therefore, a small operator can be profitable on average weeks of the season and in a down week, may find they ran into liquidity problems. In statistics, there are three questions that can be answered: What will actually happen, how much variability can be seen in the actual results, and what is the chance of something bad happening? The following questions are particularly germane in Germany, where the demand for tourism fluctuates from season to season and from region to region.

The intent of this assignment is to: describe probability laws, perform and interpret the spreadsheet calculations, and make a defendable operating decision. The German context is furnished using public information from the Federal Statistical Office. All company-level parameters are illustrative planning assumptions; the calculations aren't provided as empirical forecasts due to the lack of the booking-level dataset. This separation allows for the separation of invented probabilities from facts of the market. The formula used in each of the actual spreadsheets is included into the appendices of the document.

Theoretical Framework & Statistical Laws

Random variables, expected value and dispersion

For a discrete random variable, the outcomes can be listed, e.g., the number of customers defaulting; for a continuous random variable, the outcomes fall within a range, e.g., realised demand represented by a continuous probability curve. A probability mass function gives probabilities for outcomes that are finite in number and a probability for a continuous variable is represented by an area under a density curve. The Expected Value is the average of the values that may be obtained from the operation, which is weighted by their probabilities, $E(X) = \text{sum}[xP(x)]$. Variance is equal to $E[(X - E(X))^2]$ and the standard deviation is the square root of the variance in the units of the original measurement. These measures are a measure of expected performance and uncertainty, but cannot be fully used to describe the catastrophic tail losses. (Illowsky & Dean, 2023).

Binomial and Poisson distributions

It is suitable for use with the Binomial law where there are a fixed number of n similar independent trials and a constant probability of an event p. Its formula is $P(X = k) = C(n,k)p^k(1-p)^{(n-k)}$; $E(X) = np$ and $Var(X) = np(1-p)$. A travel agency can use it to add up late-paying clients in a certain set of invoices. However, during a recession, there could be correlation in customer default, and credit quality can vary among customers. Parameters should thus be broken down and estimated, but not simply transferred. Poisson law: When the mean rate is the same for a fixed interval, $P(X = k) = \exp(-\lambda)\lambda^k/k!$; mean rate is λ and so is the variance. It can be used when independent arrivals and rate stability are possible, which is ideal for arrivals to a booking desk. Those conditions may be breached by bookings for specific holiday periods or holiday packages (Illowsky & Dean, 2023).

Normal distribution and decision trees

A Normal model is used to estimate the probability the demand will exceed a capacity limit with a mean μ and standard deviation σ. A standardization converts a demand threshold to a standard Normal probability, $z = (x - \mu)/\sigma$. The actual number of bookings is, however, an integer, non-negative and may be disproportionate in the event of a disruption. Therefore, a normal curve is an approximation and needs to be compared with historical observations, which may produce a better simulation or discrete model. Decision trees are used to relate probabilities to monetary outcomes. The concepts of expected monetary value (highest weighted average) and dispersion (negative-outcome probability and/or liquidity constraints) can lead to a different conclusion. A risk appetite and risk sensitivity test should be clearly defined in good governance, in line with the principles of ISO 31000. (International Organization for Standardization [ISO], 2018).

Data Analysis & Statistical Calculations

Observed German tourism pattern

According to the Destatis GENESIS monthly statistics, 497,411,242 overnight stays were recorded in the accommodation establishments in Germany in 2025. About 41.45 million nights were recorded on average each month, representing a total of 59.37 million nights in August, and 25.21 million nights in

January. The ratio for the August-January period was 2.36. The calculations are based directly on the twelve-monthly observations reported by Destatis and detailed values and formulas in Excel are found in Appendix B (Federal Statistical Office, 2026). The variation is important for practical applications of seasonal forecasts, but cannot be taken as independent hourly arrival observations for one operator for the monthly national overnight stays.

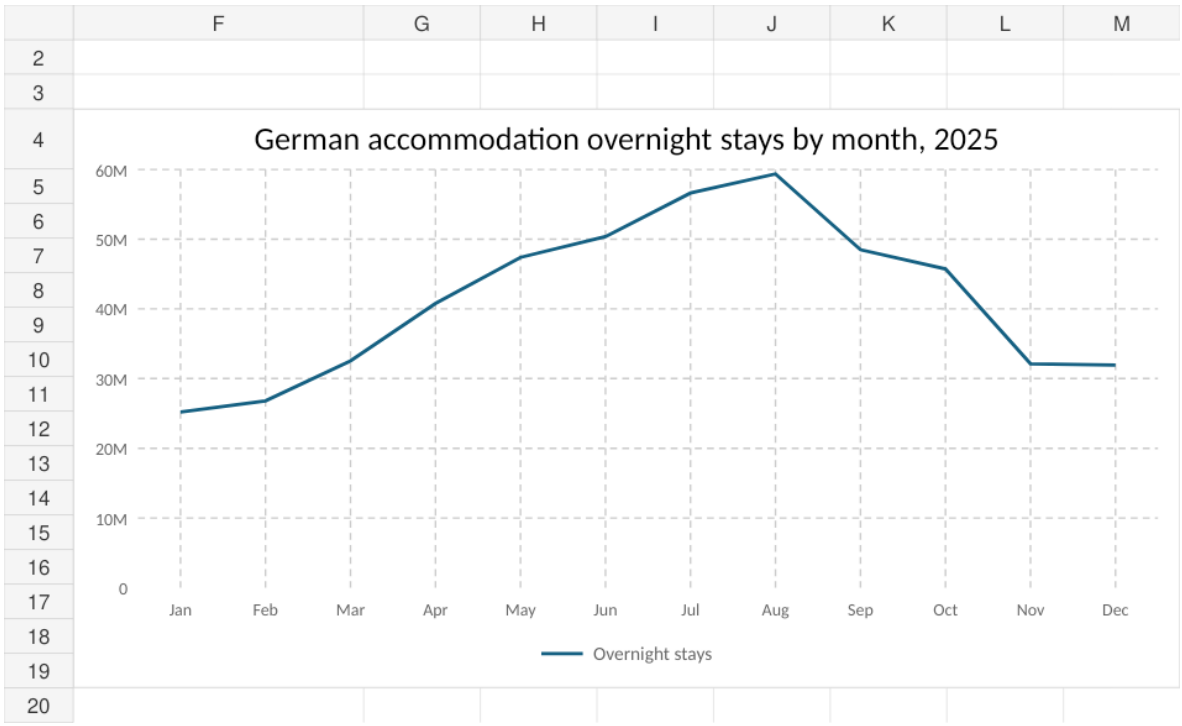


Figure 1. Monthly German accommodation overnight stays in 2025. Chart copied from the Excel workbook; underlying source: Destatis GENESIS table 45412-0014.

Binomial model: unpaid customer invoices

Suppose that a German tour operator has 30 identical credit invoices, each of which has an independent probability of 4% of default with a loss of €450 in the event of a default. These are inputs for exercise and not observed rates. The expected number of defaults is $30 \times 0.04 = 1.20$; variance is $30 \times 0.04 \times 0.96 = 1.152$; and standard deviation is 1.073 defaults. The Excel model gives $P(X \geq 2) = 1 - P(X = 0) - P(X = 1) = 0.3388$. Expected bad-debt loss equals €540 (1.20 × €450). The average loss is not so large, but it is possible that two or more defaults would occur in a trading cycle. Making deposits, examining credit limits, and/or insuring receivables that have been selected may result in minimizing exposure but the benefits must outweigh the costs.

Poisson model: peak-hour booking enquiries

Suppose the average number of independent enquiries per busy hour is 12. Using the Poisson model, the mean and standard deviation are estimated as 12 and 3.464 respectively. The chance of 16 or more enquiries in an hour is 15.56%. This does not mean that these peaks will occur consistently all year long — the average rate needs to be calculated separately for weekends, holidays and campaigns. Managers might be able to set up an overflow agent for times that they know there will be a high volume of arrivals, and track abandonment rates and compare the arrival model with the number of enquiries. If the variance is persistently larger than the mean it would indicate overdispersion and warrant testing a negative binomial model or a time-varying alternative.

Normal model: tour capacity and overselling

Suppose that the number of customers per departure is close to being normally distributed with mean $\mu = 80$ and variance $\sigma^2 = 15^2$. When the tour has 100 seats, $z = (100 - 80)/15 = 1.333$. The value for $P(D > 100)$ is calculated by Excel to be 9.12%, which means that a capacity shortage is uncommon but is of commercial relevance. About 104.67 customers are required for the 95th-percentile demand. A manager with the target of 95% accommodation for the outcomes of the demand would require approximately 105 places (which is rounded up to the nearest integer, and also subject to operational viability). To buy additional seats on this basis alone would be expensive without considering the contribution margins and cancellation terms of those seats. Furthermore, a skewed booking pattern might underestimate the peaks of bookings, if the booking pattern is strongly skewed.

Expected value, variance and decision analysis

For a tour company, there is either a fixed type of additional capacity or an outsourcing of flexible support. The market conditions are mutually exclusive so they have the probabilities of 0.25 (low), 0.50 (base) and 0.25 (high). Fixed capacity produces profits of -€500, €1,800 and €3,900; flexible capacity produces €400, €1,300 and €2,500 respectively. The expected profit is €1,750 for a fixed capacity, with a standard deviation of €1,556; and, €1,375 for flexible capacity with a standard deviation of €746. The fixed option thus makes a profit of €375 per annum on average, but has a 25% chance of making a loss. In

the specified flexible options, there is no loss. These are ‘scenario outcomes' and not historical profits, they do not include taxes, financing and secondary shocks.

	A	B	C	D	E	F
1	**DECISION TREE | Fixed vs. flexible capacity (EUR)**					
2						
3						
4	**Market state**	**Probability**	**Fixed option P/L**	**Flexible option P/L**	**P x fixed P/L**	**P x flex P/L**
5	Low	25%	-500	400	-125	100
6	Base	50%	1,800	1,300	900	650
7	High	25%	3,900	2,500	975	625
8						
9	Totals / expected value	100%			1,750	1,375
10						
11	**Decision metric**	**Fixed option**	**Flexible option**	**Meaning**		
12	Expected profit	1,750.00	1,375.00	Risk-neutral criterion		
13	Population variance	2,422,500.00	556,875.00	Probability-weighted		
14	Standard deviation	1,556.44	746.24	Outcome volatility		
15	P(loss)	25%	0%	Fixed has loss in low state		
16	EV preference	Fixed		Fixed higher EV		
17	Downside preference	Flexible		Proposed policy <=20% loss probability		

Figure 2. Excel decision-model output: probability-weighted payoffs, dispersion and downside comparison (illustrative).

Discussion & Economic Implications

What corporate cases show

Disciplined, capital-intensive risk management is a German model, provided by Munich Re. At the end of 2025, the company's Solvency II ratio was 298%, up from 287% a year before. While its disclosures have been published, these publications do not show that it is the modelling which ensured its success (Munich Re, 2026). The 2012 “London Whale” trade bust by JPMorgan cost the firm over US$6.2 billion, according to a US Senate report. The case study at Yale chronicles a modification to a value-at-risk model which seemed to be bringing the risk down by 50%, but was later discovered to be incorrectly applied. There were concerns with modelling, further exacerbated by trading limitation violations and poor challenge mechanisms (U.S. Senate Permanent Subcommittee on Investigations, 2013; Zeissler & Metrick, 2019).

In September 1998, fourteen private institutions contributed some $3.6 billion to prevent disorderly liquidation and the Federal Reserve organized the talks without investing any of its own funds (Fleming & Liu, 2013). The history lessons presented here demonstrate the folly of assuming that a low computed loss probability is sufficient for resilience for a travel business. So, even with seemingly sound models, parameter error, dependence, cash mismatches, and management incentives can take the place of the model. Nor should a story of success or failure single out the victory as having come from any single statistical practice.

Quantitative risk-management proposal

For the illustrative operator a decision matrix adds the probability of loss, minimum cash-buffer rule, expected profit and profit volatility. A risk-neutral objective would give fixed capacity a win of €375. Fixed capacity fails as it is expected to have a downside of 25% under the proposed maximum 20% ALP, so it would be prudent for management to choose flexible capacity unless it can insure or contractually reduce its exposure. The rule is not a statutory threshold in Germany, but rather a management preference. A version-controlled Excel dashboard should be provided with weekly booking data and credit ageing data and a quarterly validation should involve comparing forecast probabilities with actual counts, exceptions to be documented and parameters adjusted. A stress case should be a single event that simulates both lower bookings, payment default on connected transactions, and supplier disruption – not disturb one assumption at a time.

Economic advantages: more responsive staffing, avoiding unnecessary credit losses and more timely capacity buying. GDPR requirements must be taken into account when analysing information related to booking or payment of personal details. Managerial judgement should be used and not replaced by probability estimates. The operator should evaluate the value of premiums in exchange for the protection they provide and adjust the decision when supplier pricing and/or customer behavior change. (ISO, 2018).

Conclusion & Recommendations

These models (Binomial, Poisson, Normal) all solve different operational questions: payment defaults, arrival counts and capacity exceedances. The expected value is an average of commercial returns and the variance, standard deviation and downside probability reveal further risk. The calculations in Excel provide a transparent worked example, while official German tourist statistics show that there is significant seasonality. The operator level parameters, however, should not be used as measured facts of the German market and the assumed distributions may be used only if the assumptions are reasonably met.

The management decision suggested is to go with flexible capacity in the beginning in order to maintain a positive profit for all three of the stated scenarios and satisfy the illustrative 20% downside tolerance. Management should set up monthly parameter updates, create separate models for peak seasons, set cash and credit limits, set the controls for the deposits that customers can make, set escalation thresholds and ensure that the risk register is independently reviewed every month. It should review the fixed capacity assumption if there is reliable operating data that would support the review; and incorporate scenario stress testing in addition to regular probability analysis. These measures offer a practical basis for making commercial decisions in the face of uncertainty, but do not give mathematical certainty.

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Appendix

Appendices: Appendix A. Excel model inputs and assumptions

	A	B	C
1	**STATISTICS | Model assumptions and sources**		
2			
3			
4	**Model / Data item**	**Assumption / value**	**Meaning**
5	Location	Germany	Tour operator
6	Period	One cycle	Independent scenarios
7	Credit sales (n)	30	Number of invoices
8	Default probability (p)	4.0%	Independent credit events
9	Enquiry arrival rate (lambda)	12	Per peak-hour
10	Tour demand mean (mu)	80	Customers per departure
11	Tour demand standard dev.	15	Customers per departure
12	Tour capacity	100	Seats / tour
13	Loss per default (EUR)	450	Loss given default
14	Low-market probability	25%	Decision tree weight
15	Base-market probability	50%	Decision tree weight
16	High-market probability	25%	Decision tree weight
17	Peak staff alert trigger	16	Enquiries per hour
18	Loss probability trigger	20%	Maximum tolerable downside

Appendix B. Real German monthly tourism data

	A	B	C	
1				
2				
3				
4	**Month**	**Overnight stays**	**Share of annual total**	**Citation**
5	Jan	25,207,171	5.1%	Destatis GENESIS 4
6	Feb	26,809,247	5.4%	Destatis GENESIS 4
7	Mar	32,549,791	6.5%	Destatis GENESIS 4
8	Apr	40,783,879	8.2%	Destatis GENESIS 4
9	May	47,397,052	9.5%	Destatis GENESIS 4
10	Jun	50,364,050	10.1%	Destatis GENESIS 4
11	Jul	56,625,846	11.4%	Destatis GENESIS 4
12	Aug	59,367,392	11.9%	Destatis GENESIS 4
13	Sep	48,484,787	9.7%	Destatis GENESIS 4
14	Oct	45,735,141	9.2%	Destatis GENESIS 4
15	Nov	32,132,838	6.5%	Destatis GENESIS 4
16	Dec	31,954,048	6.4%	Destatis GENESIS 4
17				
18	Annual total	497,411,242		
19	Monthly mean	41,450,937		
20	Monthly population SD	11,063,599		
21	Peak-to-trough ratio	2.36		

Appendix C. Binomial invoice-default calculations

	A	B	C	D	E
1	**BINOMIAL | Independent invoice-default counts**				
2					
3					
4	**Default count k**	**P(X = k)**	**P(X <= k)**	**Expected defaults**	**Risk statistic**
5	0	0.2939	0.2939		n
6	1	0.3673	0.6612		p
7	2	0.2219	0.8831		E[X]
8	3	0.0863	0.9694		Var(X)
9	4	0.0243	0.9937		SD(X)
10	5	0.0053	0.9989		P(X >= 2)
11	6	0.0009	0.9999		Expected bad-debt loss (€)
12	7	0.0001	1.0000		Risk rule
13	8	0.0000	1.0000		
14	9	0.0000	1.0000		

The results shown are calculated with work in the Excel functions COMBIN and linked cells at the input, but not by inserting tables into the file manually.

Appendix D. Poisson arrivals and peak staffing

	A	B	C	D	
1	POISSON | Customer enquiry count per peak hour				
2					
3					
4	Enquiries k	P(X = k)	Cumulative P(X<=k)	Staffing relevance	Statistic
5	0	0.0000	0.0000	Routine	Mean per hou
6	1	0.0001	0.0001	Routine	Variance
7	2	0.0004	0.0005	Routine	Standard devi
8	3	0.0018	0.0023	Routine	P(X >= 16)
9	4	0.0053	0.0076	Routine	Minimum esc
10	5	0.0127	0.0203	Routine	
11	6	0.0255	0.0458	Routine	
12	7	0.0437	0.0895	Routine	
13	8	0.0655	0.1550	Routine	

The EXP and FACT functions can be used in formula outputs. If a companion is used, then counts 0-25 are kept.

Appendix E. Normal demand and seat-capacity risk

	A	B	C	D	E
1	NORMAL | Departure demand and capacity risk				
2					
3					
4	Seat threshold	P(D > seats)	Z-score	Interpretation	Statistic
5	60	90.9%	-1.333333333	Capacity / lower	Mean demand
6	70	74.8%	-0.666666667	Capacity / lower	Std dev.
7	80	50.0%	0	Capacity / lower	Current tour capacity
8	90	25.2%	0.666666667	Capacity / lower	P(D > 100)
9	100	9.1%	1.333333333	Capacity / lower	95th-percentile demand
10	110	2.3%	2	Above capacity	Shortfall at capacity?
11	120	0.4%	2.666666667	Above capacity	
12					

Appendix F. Expected-value and decision-tree model

	A	B	C	D
1	**DECISION TREE | Fixed vs. flexible capacity (EUR)**			
2				
3				
4	**Market state**	**Probability**	**Fixed option P/L**	**Flexible option P/L**
5	Low	25%	-500	400
6	Base	50%	1,800	1,300
7	High	25%	3,900	2,500
8				
9	Totals / expected value	100%		
10				
11	**Decision metric**	**Fixed option**	**Flexible option**	**Meaning**
12	Expected profit	1,750.00	1,375.00	Risk-neutral criterion
13	Population variance	2,422,500.00	556,875.00	Probability-weighted
14	Standard deviation	1,556.44	746.24	Outcome volatility
15	P(loss)	25%	0%	Fixed has loss in low state
16	EV preference	Fixed		Fixed higher EV
17	Downside preference	Flexible		Proposed policy <=20% loss probability

Appendix G. Statistical control and implementation roadmap

	A	B	C
1	**GOVERNANCE | Quantitative risk-assessment roadmap**		
2			
3			
4	**Step**	**Action**	**Frequency**
5	1. Record data	Booking, demand, arrivals and loss events	Daily at source
6	2. Check quality	Duplicates, seasonality, missing values	Weekly
7	3. Fit distributions	Binomial/Poisson/Normal where assumptions hold	Monthly
8	4. Validate	Compare observed frequencies and forecasts	Quarterly
9	5. Decide	EV, SD, tail/loss probability and cash limits	At each decision
10	6. Stress test	Demand shock, dependence, supplier failure	Quarterly
11	7. Escalate	P(loss)>20%, repeated defaults, staffing peaks	As triggered
12	8. Document	Keep versioned inputs, outputs and authorisation	Continuous

Operational governance activities using spreadsheets with named frequency and function responsible.

Appendix H. Corporate case-evidence register

	A	B	C	
1				
2				
3				
4	**Organisation**	**Reference year**	**Published result**	**Lesson**
5	Munich Re	2025	Solvency II ratio 298%	Risk-model governance
6	JPMorgan London Whale	2012	Losses >= $6.2bn	Model implementation
7	LTCM	1998	$3.6bn private rescue	Tail dependence, levera

Published company events are distinguished from the illustrative travel operator exercise.