



Intelligent systems for the management of airport commercial facilities considering passenger satisfaction: a neuro-fuzzy approach

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Brazil, August 20 and 21

Workshop ITA-MIT on big data analytics for air transportation

SUMMARY

01

INTRODUCTION

02

DATA

03

METHODOLOGY

04

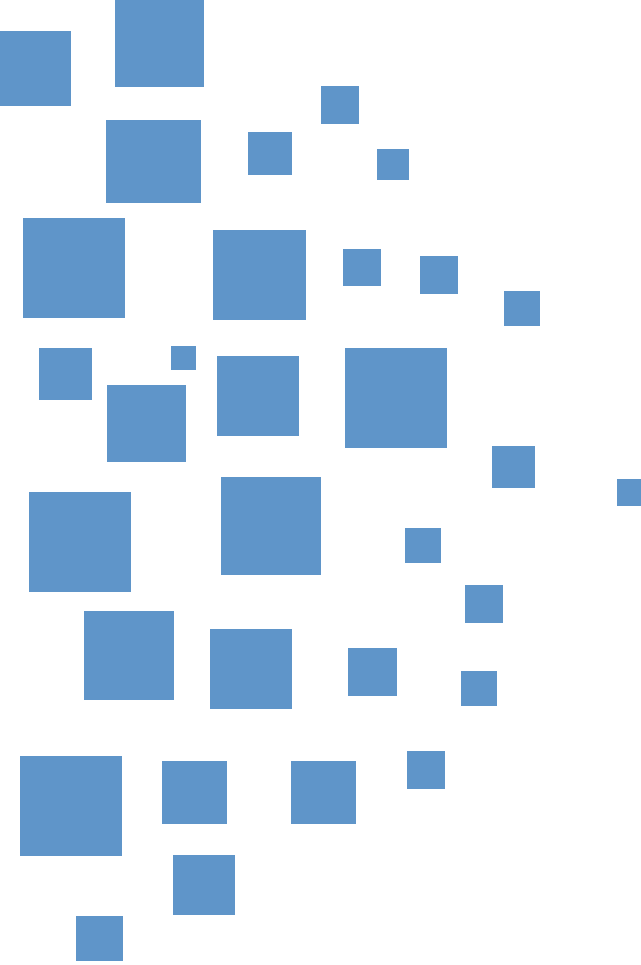
RESULTS

05

FINAL CONSIDERATIONS



Some Airport Big Data Analytics Applications



Airlines

Customizing the customer experience



Commercial Facilities

Know in advance customer profile, behaviour and habits



Tracking

Flow Passenger
Real-time Baggage Status



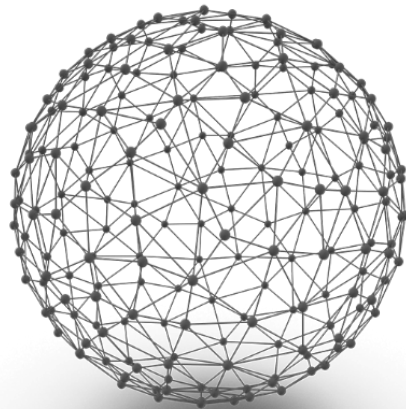
Check-in

Verify which passengers made online check-in or use the service desk



Security

Facial recognition and behavioural patterns assisting with security at the airport



Big Data Analytics

INTELLIGENT SYSTEMS FOR THE MANAGEMENT

Full Exploitation Of Airport Commercial Opportunities to improve non-aeronautical revenues based on customer experience



Non-aeronautical
revenues



Customer
Experience



Layout



Passenger
Flow



Neuro
Fuzzy



Database

01

SECONDARY DATA

CIVIL
AVIATION
SECRETARIAT
SURVEY

02

PRIMARY DATA

SURVEY WITH
STRUCTURED
FORMS

03

SECONDARY DATA

ANNUAL
REPORT

04

SECONDARY DATA

AIRPORT'S
WEB SITE

05

SECONDARY DATA

REGULATORY
AGENCIES

SINCE 2013

Passenger satisfaction
User Profile

Permanent Survey
21 main Brazilian airports

IN LOCO

User Profile
Purchase Behavior
Passenger Satisfaction

REVENUES

Aeronautical
Non-Aeronautical

LAYOUT

Numbers, types, and
location of commercial
establishments

TRAFFIC

Passenger movement

Pilot Project
Tancredo Neves/Belo Horizonte Airport

Database

Pilot Project – IN LOCO Survey & Collected Data

Tancredo Neves/Belo Horizonte Airport

- January 17-18, 2019
- 174 interviewees
- Public and Restricted Area

Commercial Performance

User Profile

Gender
Purpose
Age (years)
Education Level
Income
Frequency
Feeling
Waiting time (h)

Purchase Behavior

Value Spent
Store/Branding
Product
Location
Web access

Satisfaction

Product Quantity & Quality
Product Value
Product cost benefit
Store comfort & space
Store availability & location
Store employee cordiality
Store queue time
Signaling to find the store

Scale 0 to 10
very bad - very good

Revenues

Aeronautical
Non-aeronautical

Layout

Store types
Location

Traffic

Passenger movement



Database

Permanent Survey
21 main Brazilian airports
Operational Performance

CIVIL
AVIATION
SECRETARIAT



Subset

Airport & Flight

Airport name
Process
Terminal
Flight type

Passenger Profile

Socio-demographic
Travel Purpose
Frequency
Waiting time

Satisfaction

Store Quantity & Quality
Product Value
Store Queue Time
Store Employee Cordiality

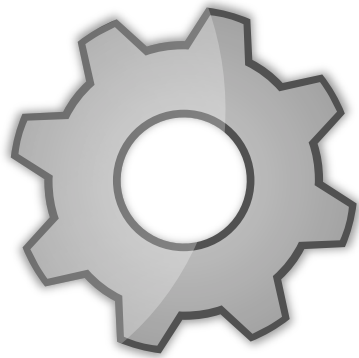
Scale 1 to 5

very bad - very good

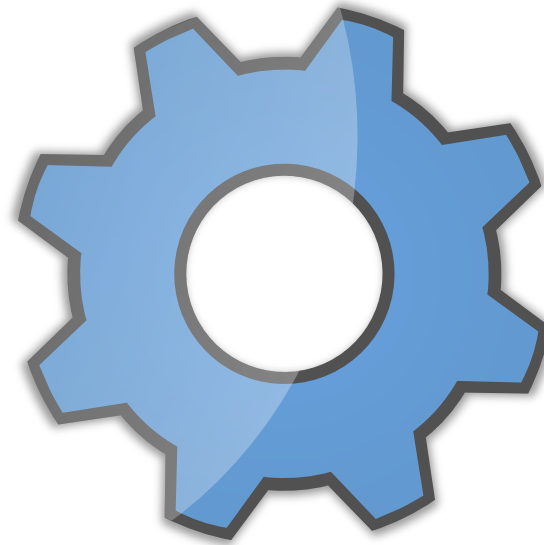
= 431844 rows X 90 columns (RAW DATA)

Collection Period: May 29, 2013 to March 30, 2019

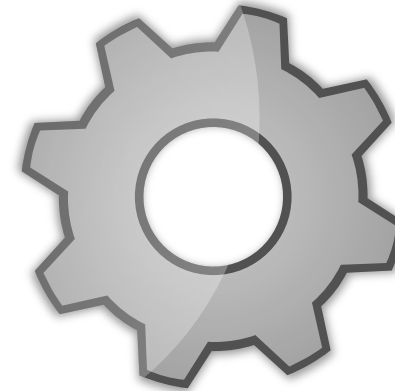
METHODOLOGY



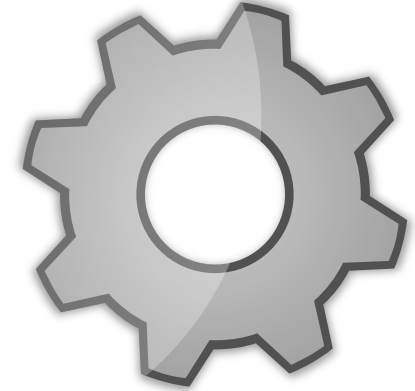
Data Science



Neural Network



Fuzzy



**Programming
language**



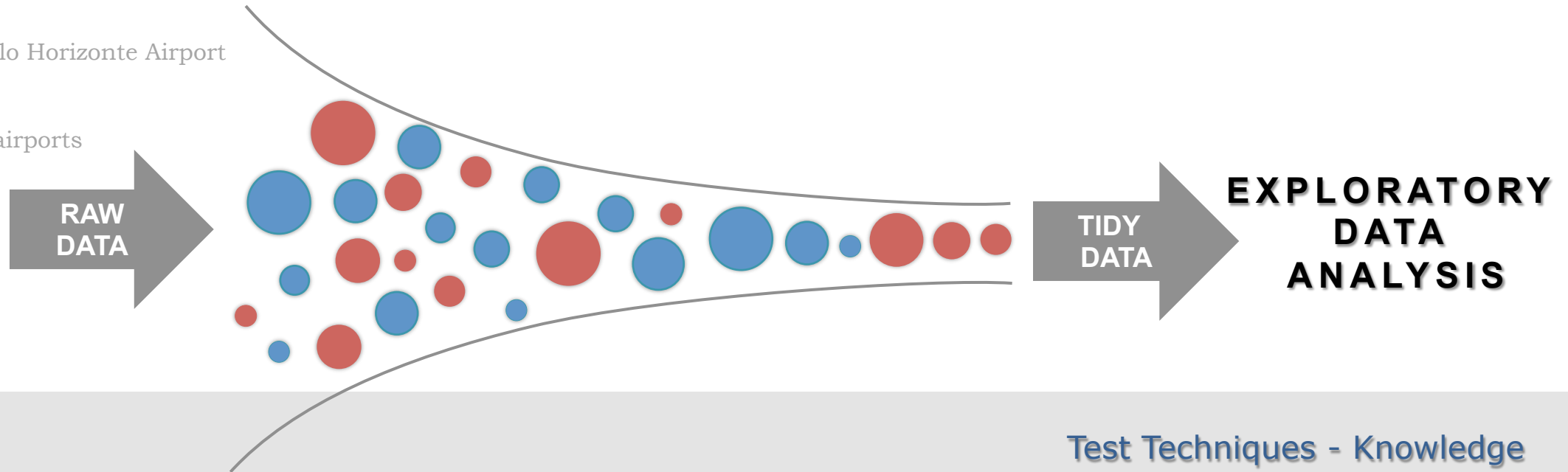
Data Science

Pilot Project

Tancredo Neves/Belo Horizonte Airport

Permanent Survey

21 main Brazilian airports



Tancredo Neves/Belo Horizonte Airport

LINEAR REGRESSION



- User Profile
- Purchase Behavior
- Passenger Satisfaction

Tancredo Neves/Belo Horizonte Airport

NET PROMOTER SCORE



- Passenger Satisfaction (LOYALTY)

Tancredo Neves/Belo Horizonte Airport

VISUALIZATIONS



- Layout
- Revenues
- Traffic

21 main Brazilian airports

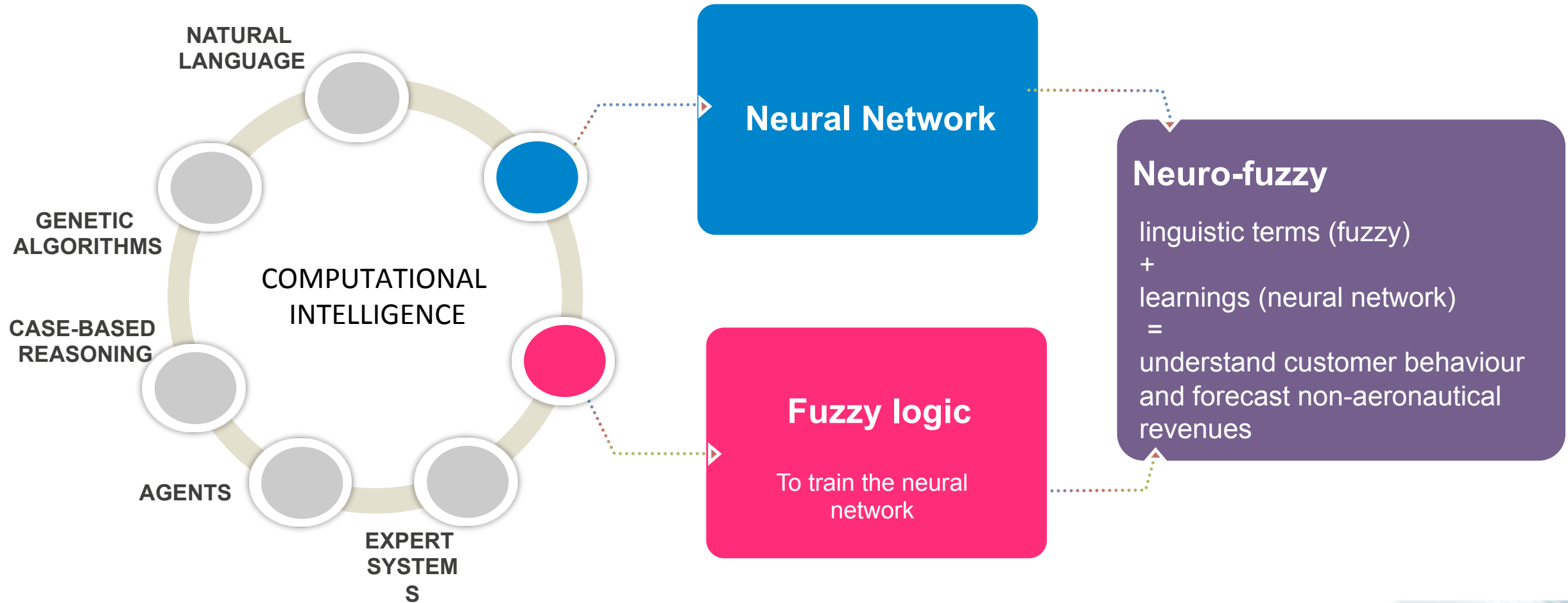
MEAN / GROUPING



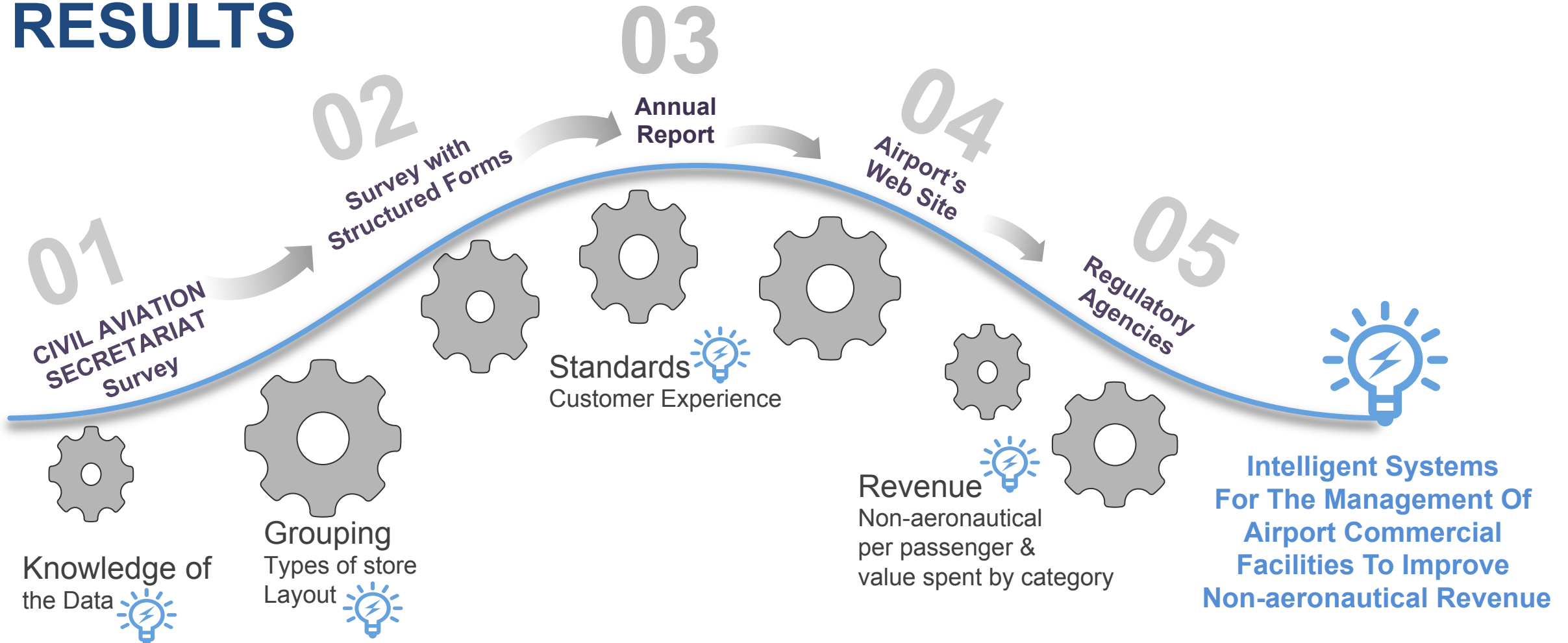
- Passenger Satisfaction



Computational Intelligence



RESULTS



Test Techniques

EXPLORATORY DATA ANALYSIS

Tancredo Neves/Belo Horizonte Airport

LINEAR REGRESSION

- User Profile
- Purchase Behavior
- Passenger Satisfaction

STUDY BEHAVIOR OF VARIABLES CONSIDERING THE FOLLOWING INDEPENDENT VARIABLES AS A BASIS:
feelings relax, age 18-25, food & beverage store, frequency first, gender male, travel leisure, cafeteria store

Source: SILVA et al, 2019

VALUE SPENT PER PASSENGER BY CATEGORIES	VALUE SPENT			VALUE SPENT			VALUE SPENT			
			Confidence Intervals			Confidence Intervals			Confidence Intervals	
	Predictors	Estimates	Lower	Upper	Estimates	Lower	Upper	Estimates	Lower	Upper
	(Intercept)	35.72 ***	18.25	53.18	31.44 ***	18.86	44.01	27.74 ***	12.21	43.27
	Travel Business	-3.56	-31.72	24.59						
	Travel Others	78.62 **	26.23	131.01						
	Retail stores				120.73 ***	73.68	167.79			
	Accessories							102.26	1.63	202.89
	Crafts							10.26	-90.37	110.89
	Imported item/ Perfume							269.76 ***	197.76	341.76
Footwear							72.26	-28.37	172.89	
Diner/Pizzeria							5.95	-19.95	31.86	
Bookstore							22.26	-78.37	122.89	
Restaurant							10.69	-20.96	42.33	
Ice cream shop							12.26	-88.37	112.89	
Observations	84			84			84			
R ² / adjusted R ²	0.104 / 0.082			0.236 / 0.226			0.440 / 0.380			
* p<0.05 ** p<0.01 *** p<0.001										
	F-statistic: 4.708 on 2 and 81 DF, p-value: 0.1163E-01			F-statistic: 25.29 on 1 and 82 DF, p-value: 0. 2855E-05			F-statistic: 7.36 on 8 and 75 DF, p-value: 0.3529E-06			

Source: SILVA et al, 2019

SATISFACTION BY 3 DIFFERENT INDICATORS BY CATEGORIES	SATISFACTION	PRODUCT VALUE			COST BENEFIT OF THE PRODUT			SIGNAGE TO GET TO THE STORE		
	Predictors	Estimates	Confidence Intervals		Estimates	Confidence Intervals		Estimates	Confidence Intervals	
			Lower	Upper		Lower	Upper		Lower	Upper
	(Intercept)	7.93 ***	6.08	9.77	7.77 ***	5.83	9.71	5.83 ***	3.05	8.60
	Gender Female	-1.19 *	-2.21	-0.16						
	Age 26-35	0.09	-1.92	2.10	-1.32	-3.23	0.59	2.05	-0.97	5.08
	Age 36-45	-2.98 **	-4.92	-1.04	-1.99 *	-3.83	-0.15	1.98	-0.96	4.93
	Age 46-55	-1.17	-3.33	0.99	-0.37	-2.42	1.67	2.68	-0.53	5.89
	Age 56-64	-1.86	-4.21	0.49	-1.11	-3.36	1.15	0.22	-3.30	3.75
	Age > 65	-4.20 **	-7.27	-1.12	-5.54 ***	-8.43	-2.65	-5.58 *	-10.12	-1.05
	Frequency < 1				0.38	-1.49	2.24			
	Frequency 1-4				0.32	-0.89	1.53			
	Frequency 5-12				0.80	-0.77	2.36			
	Frequency > 12				2.00 *	0.29	3.72			
	Feelings Anxious							-0.72	-2.55	1.10
	Feelings Indifferent							-1.89 *	-3.65	-0.13
	Feelings Uncomfortable							0.50	-3.46	4.45
	Observations	84			84			84		
	R ² / adjusted R ²	0.285 / 0.229			0.247 / 0.156			0.222 / 0.139		
	* p<0.05 ** p<0.01 *** p<0.001									
	F-statistic: 5.112 on 6 and 77 DF, p-value: 0.0001824			F-statistic: 2.702 on 9 and 74 DF, p-value: 0.008913			F-statistic: 2.681 on 8 and 75 DF, p-value: 0.01197			

Test Techniques

Tancredo Neves/Belo Horizonte Airport

NET PROMOTER SCORE

- Passenger Satisfaction (LOYALTY)

Would the customer recommend the company to a friend?
(service or product)

0 1 2 3 4 5 6 7 8 9 10



DETRACTORS 0 - 6



NEUTRAL 7 - 8



PROMOTERS 9 - 10



Source: SILVA et al, 2019

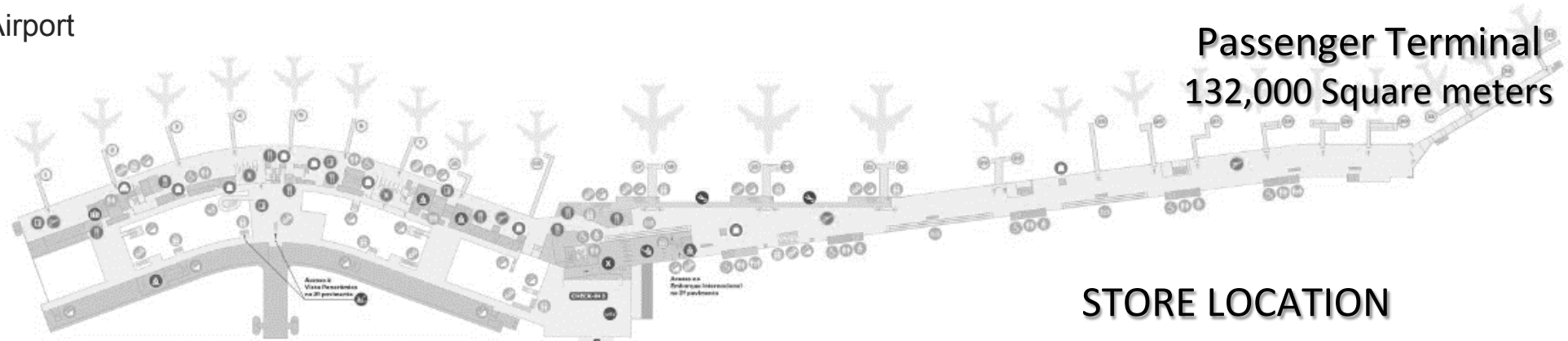
Test Techniques

EXPLORATORY DATA ANALYSIS

Tancredo Neves/Belo Horizonte Airport

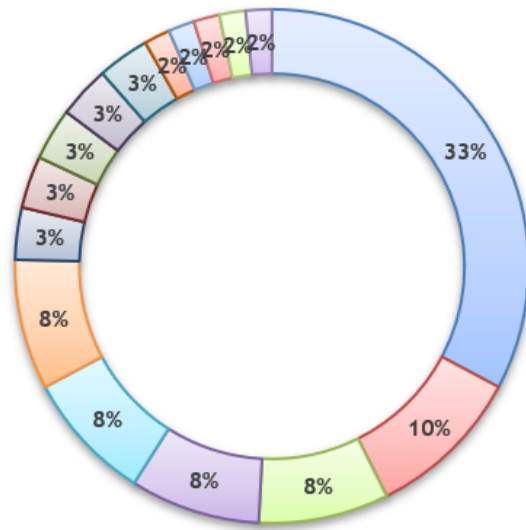
VISUALIZATIONS

Layout



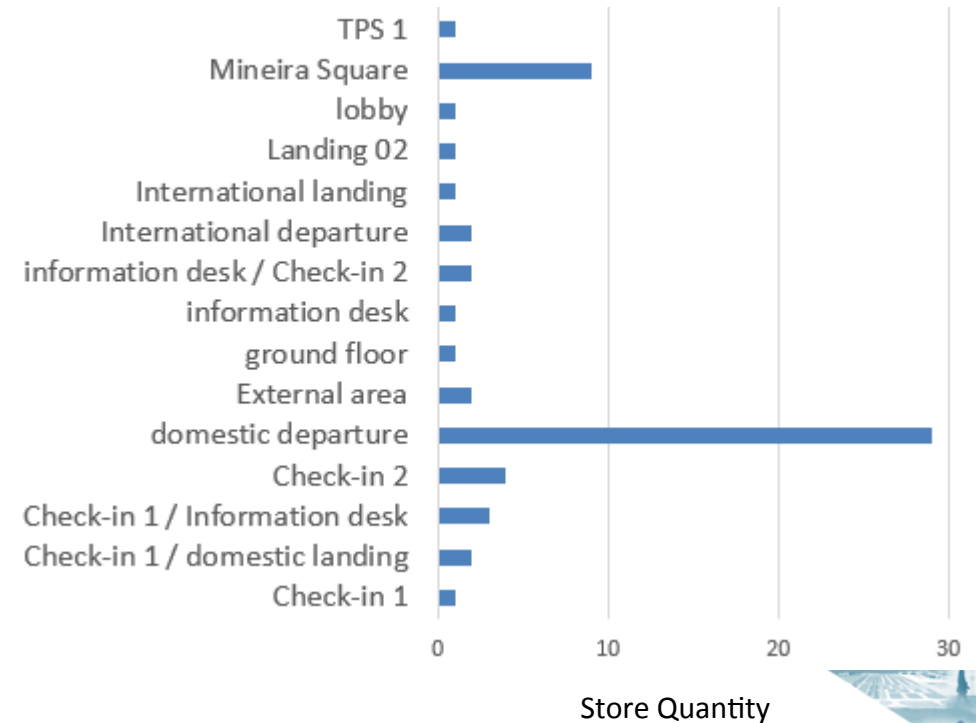
STORE TYPES & DISTRIBUTION

- Cafeteria / Snacks / Sweets / Juices
- Imported items / perfumes
- Restaurant
- Crafts / Jewellery / Semi-jewels
- Diner / Pizzeria
- Accessories
- Ice cream shop
- Brewery
- Pharmacy and Cosmetics / Makeup
- Exchange offices
- Footwear
- Perfumery
- Clothes
- Relax Lounge
- Sporting goods
- Bookstore



Source: SILVA et al, 2019

STORE LOCATION



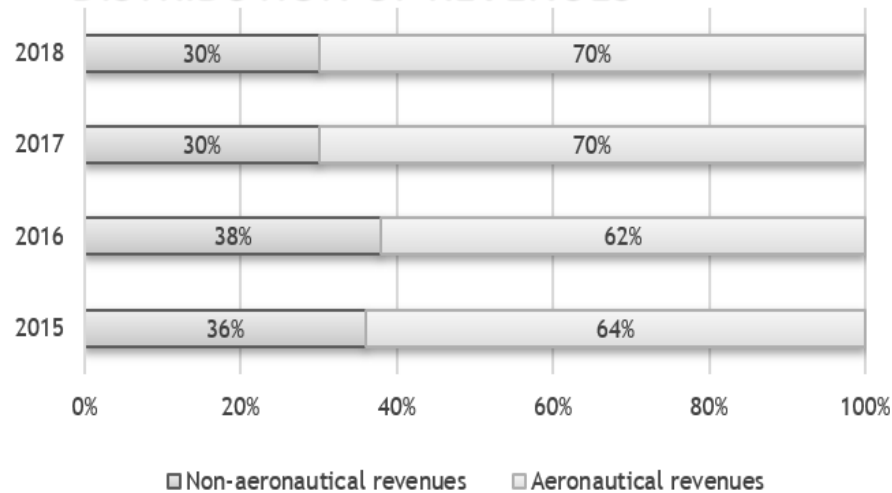
Test Techniques

Tancredo Neves/Belo Horizonte Airport

VISUALIZATIONS

Revenues

DISTRIBUTION OF REVENUES 2015 to 2018



Source: SILVA et al, 2019

Tancredo Neves/Belo Horizonte Airport

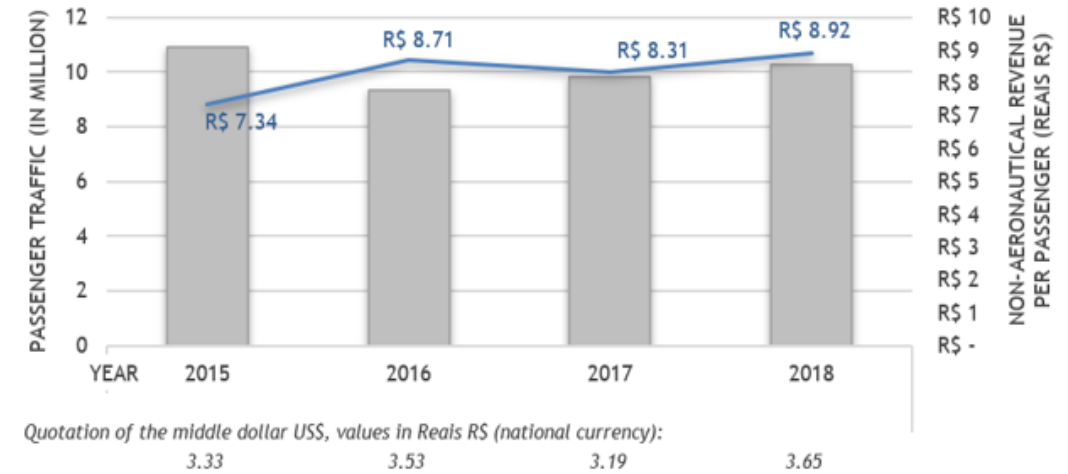
being granted to the private initiative by auction in 2013, where the concessionaire initiated the services of expansion, maintenance and exploitation of the airport in 2014 for a period of 30 years

NON-AERONAUTICAL REVENUES & PASSENGER MOVEMENT 2015 to 2018

VALUE SPENT BY CATEGORIES 2019

EXPLORATORY DATA ANALYSIS

(2018: The five busiest airports in Brazil)



Passenger traffic (in million)

Non aeronautical revenue per passenger R\$

Source: SILVA et al, 2019



Test Techniques

EXPLORATORY DATA ANALYSIS

21 main Brazilian airports

MEAN / GROUPING

Passenger Satisfaction

	Product value Snack bar/restaurant	Quantity & Quality Snack bar/restaurant	Queue Time Snack bar/restaurant	Employee Cordiality Snack bar/restaurant	Quantity & Quality Store	Product value Store	Queue Time Store	Employee Cordiality Store
	01 mean	02 mean	03 mean	04 mean	05 mean	06 mean	07 mean	08 mean
NomeAerodromo								
Aeroporto Internacional de Belém	2.941292	3.614112	NaN	NaN	3.912264	3.196926	NaN	NaN
Aeroporto Internacional de Brasília	2.217860	3.544114	3.731242	3.971873	3.329081	2.139717	3.925617	4.097428
Aeroporto Internacional de Confins	2.264898	3.433665	3.658805	3.980190	3.453861	2.537885	3.718250	3.995340
Aeroporto Internacional de Cuiabá	2.356454	3.060293	3.343062	3.537664	2.731682	2.477051	3.344477	3.367583
Aeroporto Internacional de Curitiba	2.408671	3.646510	4.090170	4.127422	3.750463	2.986671	4.205503	4.228070
Aeroporto Internacional de Florianópolis	2.897716	3.891561	NaN	NaN	3.907438	3.306897	NaN	NaN
Aeroporto Internacional de Fortaleza	2.430349	3.704884	3.937285	4.117490	3.730955	2.633718	4.015694	4.182559
Aeroporto Internacional de Maceió	3.147311	3.693716	NaN	NaN	3.938202	3.167243	NaN	NaN
Aeroporto Internacional de Manaus	2.759863	3.247752	3.342831	3.554132	3.260345	3.011648	3.555327	3.680394
Aeroporto Internacional de Natal	2.607182	3.261817	2.739550	3.181518	3.229109	2.797151	3.581522	3.754098
Aeroporto Internacional de Porto Alegre	2.589872	3.560409	3.861735	3.913751	3.579691	2.777508	4.048200	4.126820
Aeroporto Internacional de Recife	2.693786	3.848048	3.764080	3.981440	3.855735	2.641892	3.988294	4.085784
Aeroporto Internacional de Salvador	2.616071	3.706053	3.694444	3.855409	3.753643	2.732010	3.817418	3.925659
Aeroporto Internacional de São Paulo	2.229788	3.441536	3.329941	3.489759	3.514270	2.461071	3.453730	3.473668
Aeroporto Internacional de Viracopos/Campinas	2.585759	3.425508	3.745837	3.990814	3.223924	2.613633	3.778934	3.962725
Aeroporto Internacional do Rio de Janeiro	2.653388	3.539279	3.715360	3.904476	3.489877	2.839694	3.854328	4.040775
Aeroporto de Goiânia	2.695876	3.596389	NaN	NaN	3.991228	2.915663	NaN	NaN
Aeroporto de São Gonçalo do Amarante	2.377248	2.813619	3.234568	3.397862	3.012014	2.807006	3.322009	3.409692
Aeroporto de São Paulo/Congonhas	1.721828	3.437916	3.356157	4.275688	3.842992	1.761047	4.056106	4.219355
Aeroporto de Vitória	2.866909	3.824130	NaN	NaN	3.821809	3.059659	NaN	NaN
Aeroporto do Rio de Janeiro	2.064484	3.233084	3.512071	3.862350	3.350224	2.461601	3.788832	3.967109

Passenger Satisfaction Survey – Scale from 0 to 10

Triangular fuzzy numbers

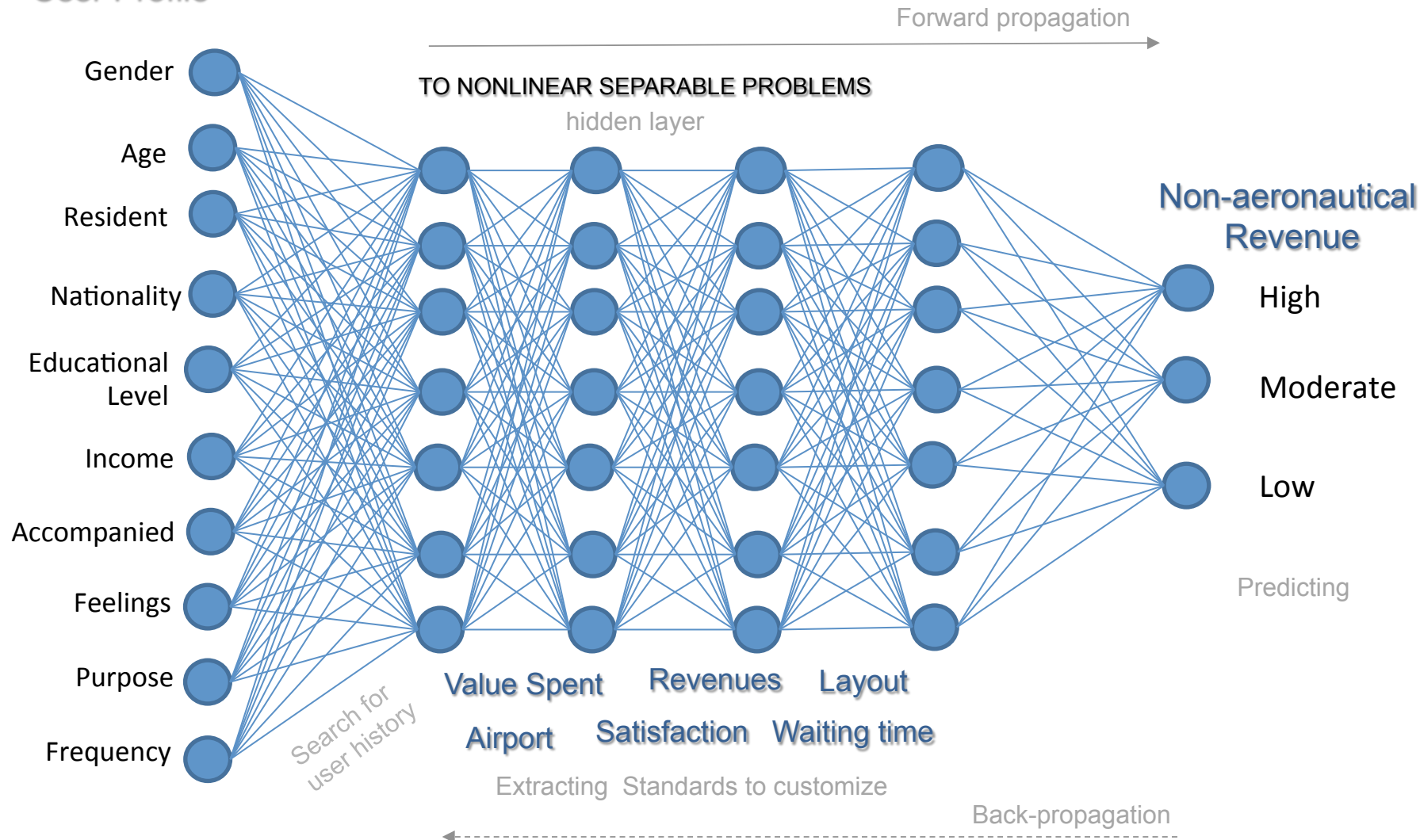
Pertinence function



Identification of Research Application Area

NEURAL NETWORK

User Profile



NEXT STEP

Multilayer Network Implementation:

- Synaptic Weight
- Training
- Activation function
- Error
- Accuracy
- Learning rate

- Continuing Exploratory Analysis Of The Permanent Survey Data Of The 21 Main Airports Of Brazil
- Implement Neural Network With Fuzzy Training And Verify Network Accuracy
- Apply Pilot Project To Other Airports
- Submit An Online Survey For A Larger Sample Number (Similar To The Pilot Project Survey)



01 Linear Regression (Pilot Project)

STUDY BEHAVIOR OF VARIABLES $R^2 < 0,5$

VALUE SPENT

Product types: ↑ imported items/perfumes
↓ cafeteria/snacks/sweets/juices

CUSTOMER SATISFACTION

Product Value	Age	+ 65 years	} + dissatisfied
Cos Benefit	Age	36 to 45 years	

02 Net Promoter Score (Pilot Project)

CUSTOMER LOYALTY

Product value
Cost benefit
Signaling to find the store

CRITICAL ZONE

Product Quantity & Quality
Store comfort & space

IMPROVEMENT ZONE

QUALITY ZONE

Store queue time
Store employee cordiality
Store availability & location

EXCELLENCE ZONE

none of the indicators with
NPS greater than 75%

03 Average / Grouping

(Permanent Survey – 21 airports)

The SP/Congonhas Airport showed lower satisfaction index for the value of products from snack bar, restaurants and commercial establishments

04 Neural Network

Multiple attribute combinations for each neuron – nonlinearly separable problems

Other different techniques were important to know about the data and enable the design of the neural network and its implementation

05 Fuzzy

Pertinence function in the analysis of satisfaction passenger





Thanks For Watching



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