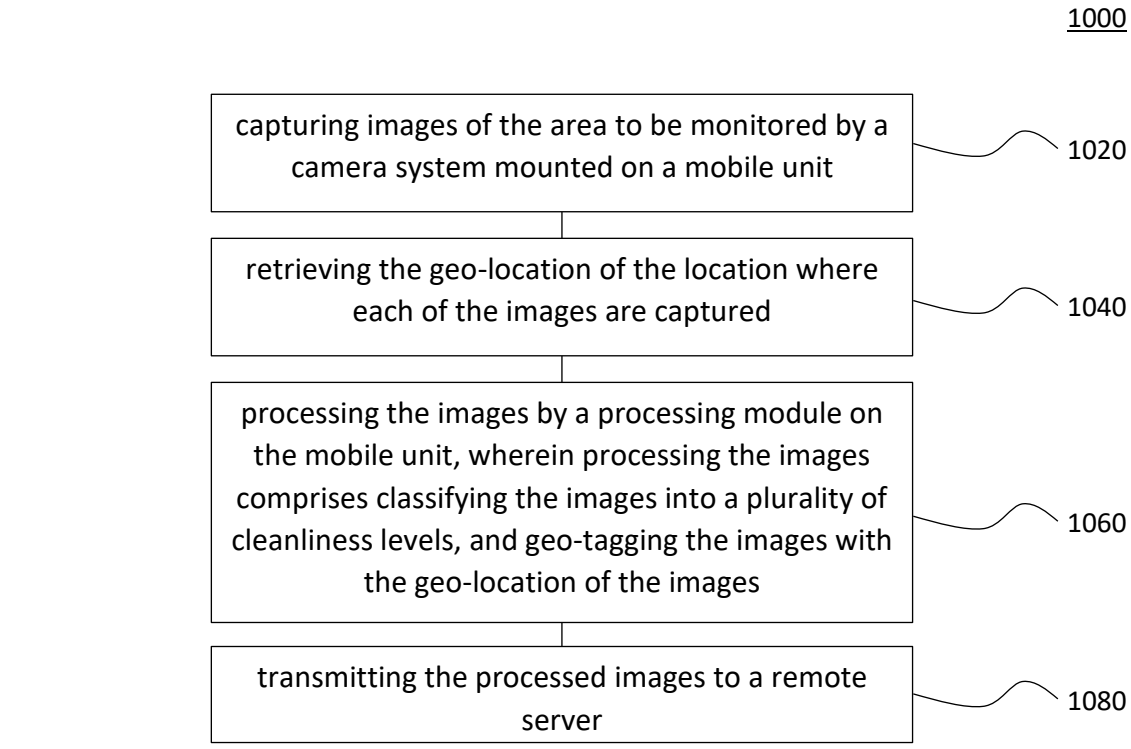

1000
capturing images of the area to be monitored by a camera system mounted on a mobile unit
1020
retrieving the geo-location of the location where each of the images are captured
1040
processing the images by a processing module on the mobile unit, wherein processing the images comprises classifying the images into a plurality of cleanliness levels, and geo-tagging the images with the geo-location of the images
1060
transmitting the processed images to a remote server
1080

Fig. 1

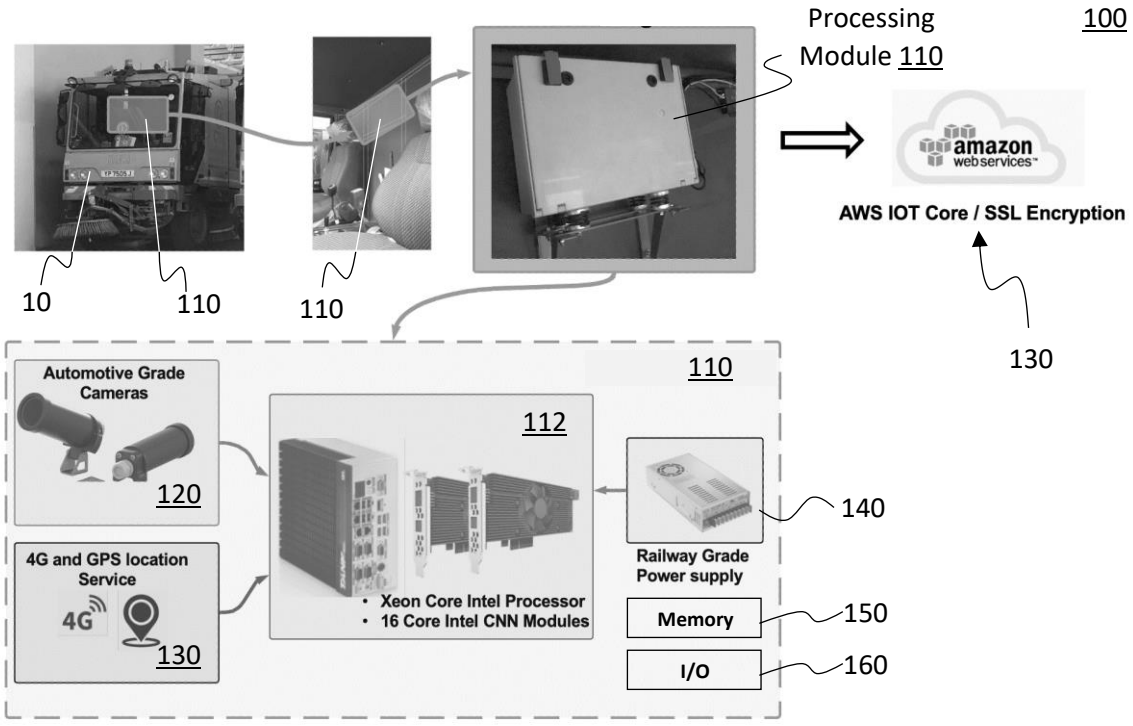

Processing Module 110
100
amazon web services
AWS IOT Core / SSL Encryption
130
10
110
110
110
Automotive Grade Cameras
120
112
4G and GPS location Service
4G
130
• Xeon Core Intel Processor
• 16 Core Intel CNN Modules
Railway Grade Power supply
140
Memory
150
I/O
160

Fig. 2

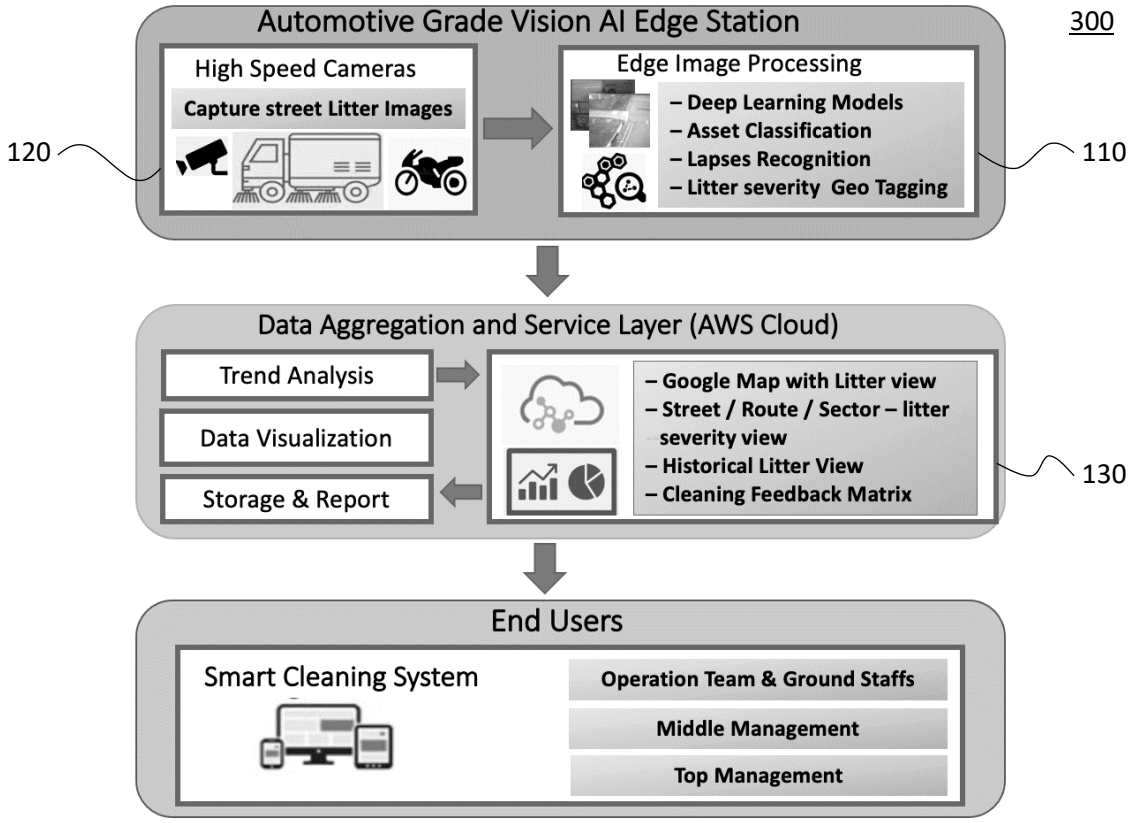

Automotive Grade Vision AI Edge Station
300
High Speed Cameras
Capture street Litter Images
120
Edge Image Processing
– Deep Learning Models
– Asset Classification
– Lapses Recognition
– Litter severity Geo Tagging
110
Data Aggregation and Service Layer (AWS Cloud)
Trend Analysis
Data Visualization
Storage & Report
– Google Map with Litter view
– Street / Route / Sector – litter severity view
– Historical Litter View
– Cleaning Feedback Matrix
130
End Users
Smart Cleaning System
Operation Team & Ground Staffs
Middle Management
Top Management

Fig. 3

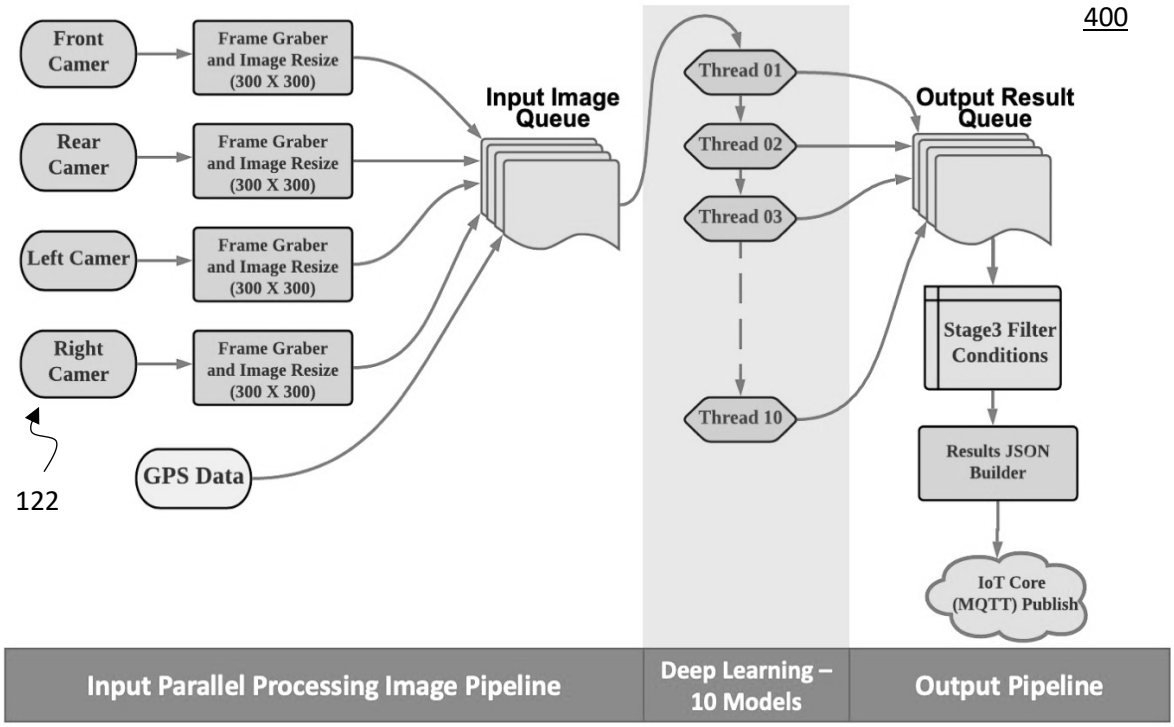

400
Front Camer
Rear Camer
Left Camer
Right Camer
Frame Graber and Image Resize (300 X 300)
Frame Graber and Image Resize (300 X 300)
Frame Graber and Image Resize (300 X 300)
Frame Graber and Image Resize (300 X 300)
GPS Data
122
Input Image Queue
Thread 01
Thread 02
Thread 03
Thread 10
Output Result Queue
Stage3 Filter Conditions
Results JSON Builder
IoT Core (MQTT) Publish
Input Parallel Processing Image Pipeline
Deep Learning – 10 Models
Output Pipeline

Fig. 4

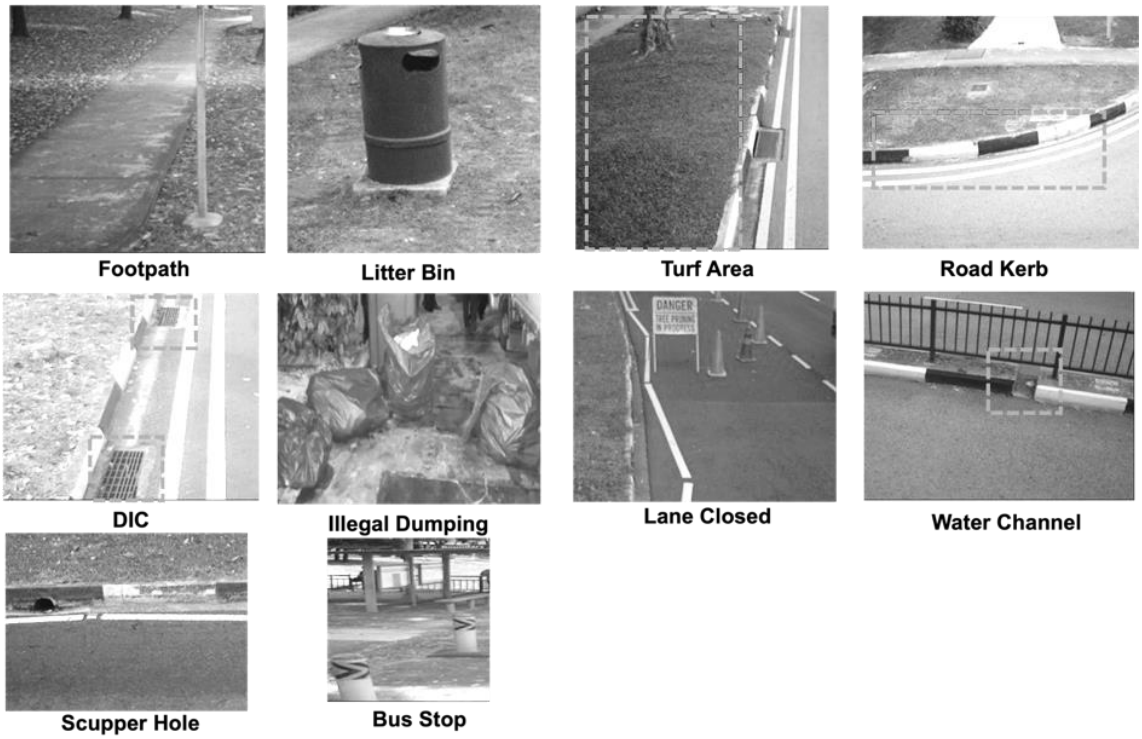

Footpath
Litter Bin
Turf Area
Road Kerb
DIC
Illegal Dumping
DANGER
Lane Closed
Water Channel
Scupper Hole
Bus Stop

Fig. 5

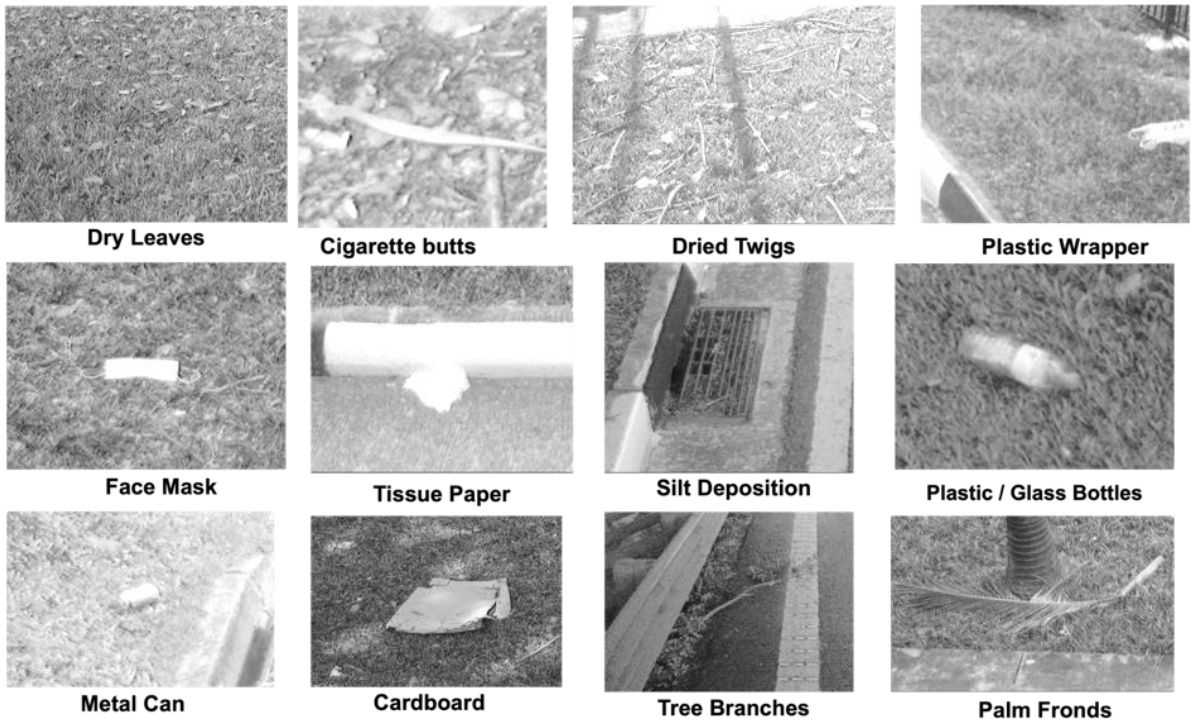

Dry Leaves
Cigarette butts
Dried Twigs
Plastic Wrapper
Face Mask
Tissue Paper
Silt Deposition
Plastic / Glass Bottles
Metal Can
Cardboard
Tree Branches
Palm Fronds

Fig. 6

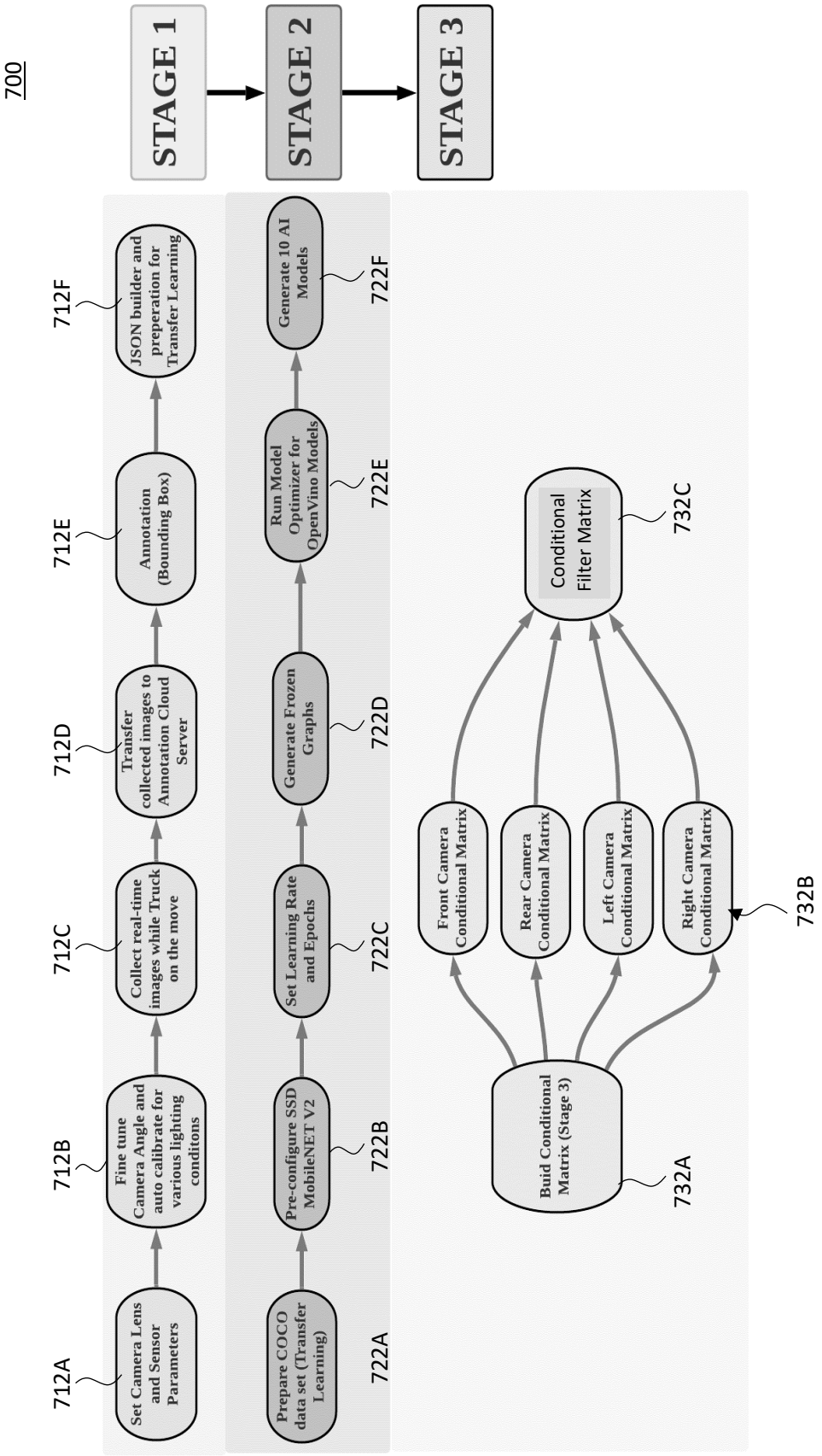

700
STAGE 1
STAGE 2
STAGE 3
712A
Set Camera Lens and Sensor Parameters
712B
Fine tune Camera Angle and auto calibrate for various lighting conditons
712C
Collect real-time images while Truck on the move
712D
Transfer collected images to Annotation Cloud Server
712E
Annotation (Bounding Box)
712F
JSON builder and preperation for Transfer Learning
722A
Prepare COCO data set (Transfer Learning)
722B
Pre-configure SSD MobileNET V2
722C
Set Learning Rate and Epochs
722D
Generate Frozen Graphs
722E
Run Model Optimizer for OpenVino Models
722F
Generate 10 AI Models
732A
Buid Conditional Matrix (Stage 3)
732B
Front Camera Conditional Matrix
Rear Camera Conditional Matrix
Left Camera Conditional Matrix
Right Camera Conditional Matrix
732C
Conditional Filter Matrix

Fig. 7

800

Model Number	Assets and Refuse Group
MODEL 1	ROAD, DIVIDER_GATE, CONSTRUCTION_WORK, ZEEBRA_CROSSING, BARRY_GUARD, PLANTING
MODEL 2	ROAD-KERB,SCUPPER-HOLE
MODEL 3	TURF-AREA
MODEL 4	FOOTPATH, DIC
MODEL 5	BUS-STOP
MODEL 6	LANE-CLOSED
MODEL 7	PLASTIC-WRAPPER,TISSUE-PAPER,MASK,PACKAGING
MODEL 8	DEBRIS, CARDBOARD, METAL-CAN, PLASTIC-GLASS-BOTTLE
MODEL 9	DRY-LEAVES,TREE-BRANCHES, OTHERS, DRY-LEAVES, DRY-LEAVES, PALM-FRONDS, DRIED-TWIGS, DRY-LEAVES
MODEL 10	CIGARETTE-BUTTS, OVERGROWN-VEGETATION, SILT-DEPOSITION

Fig. 8

10

12



Mobile Cleaning Unit

14



Mobile Inspecting Unit

Fig. 8A

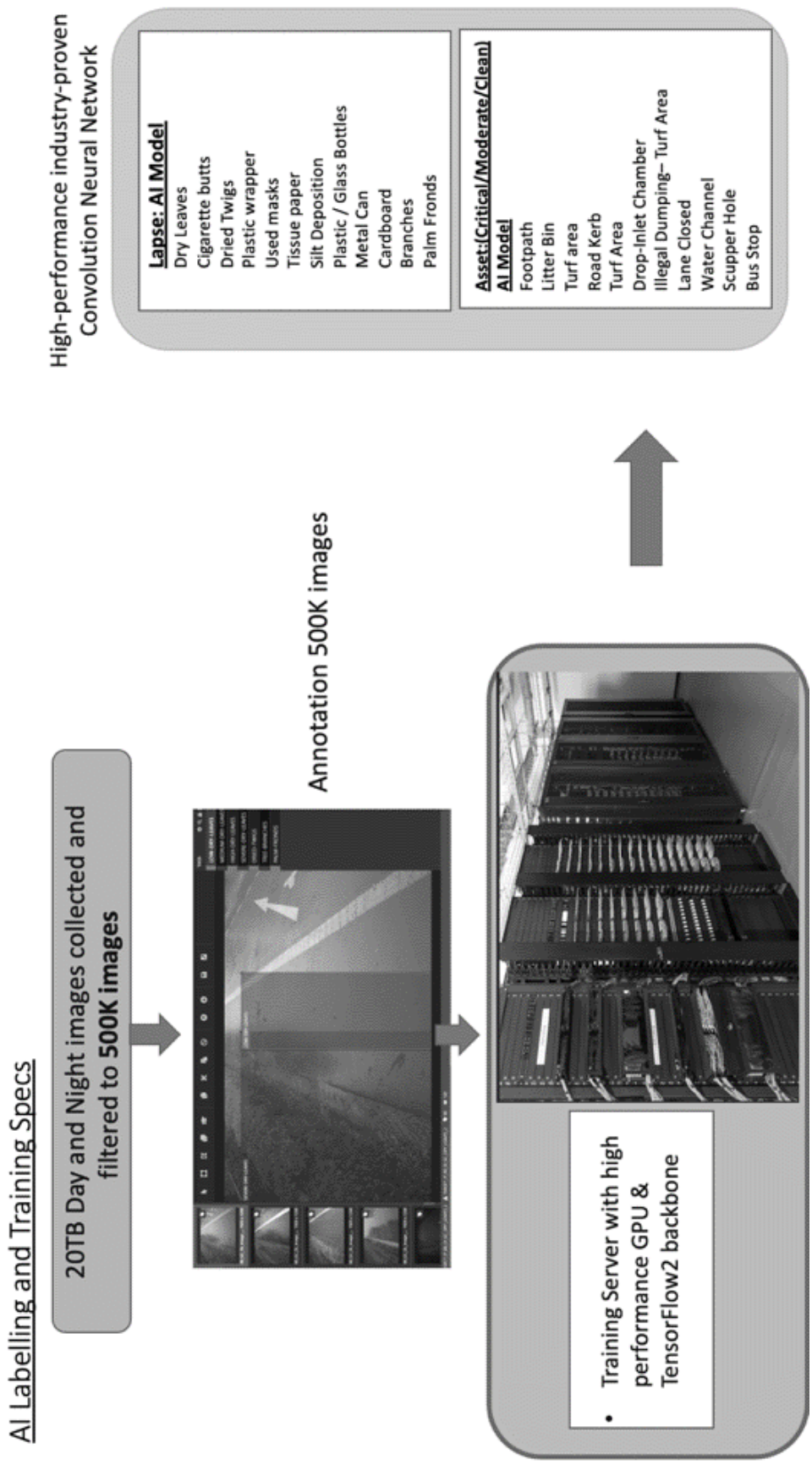

900
AI Labelling and Training Specs
20TB Day and Night images collected and filtered to 500K images
Annotation 500K images
Training Server with high performance GPU & TensorFlow2 backbone
High-performance industry-proven Convolution Neural Network
Lapse: AI Model
Dry Leaves
Cigarette butts
Dried Twigs
Plastic wrapper
Used masks
Tissue paper
Silt Deposition
Plastic / Glass Bottles
Metal Can
Cardboard
Branches
Palm Fronds
Asset:(Critical/Moderate/Clean)
AI Model
Footpath
Litter Bin
Turf area
Road Kerb
Turf Area
Drop-Inlet Chamber
Illegal Dumping– Turf Area
Lane Closed
Water Channel
Scupper Hole
Bus Stop

Fig. 9



Fig. 10

1100

Assets - Condition for Day (7am to 6pm)					
Sl NO	**Day Assets**	**Camera**	**Prediction Confidence Threshold**	**Condition for "Presence"**	**Condition for "Absence"**
1	ROAD-KERB CLEAR	CAM1,CAM2,CAM3,CAM4	-	-	-
2	ROAD-KERB MODERATE	CAM1,CAM2,CAM3,CAM4	>10	-	-
3	ROAD-KERB CRITIACL	CAM1,CAM2,CAM3,CAM4	>20	-	-
4	SCUPPER-HOLE CLEAR	CAM1,CAM2,CAM3,CAM4	-	-	-
5	SCUPPER-HOLE MODERATE	CAM1,CAM4	>20	-	-
6		CAM2,CAM3	>15	-	-
7	SCUPPER-HOLE CRITICAL	CAM1,CAM4	>20	-	-
8		CAM2,CAM3	>20	-	-
9	TURF-AREA CLEAR	CAM1,CAM2,CAM3,CAM4	-	-	DIVIDER_GATE, ZEEBRA_CROSSING,BARRY_GUARD, PLANTING,CONSTRUCTION_WORK
10	TURF-AREA MODERATE	CAM1,CAM4	>50	-	
11			>20 and <50	DRY-LEAVES,DRIED-TWIGS,PALM-FROND	
12		CAM2,CAM3	>40	-	
13			>20 and <40	DRY-LEAVES,DRIED-TWIGS,PALM-FROND	
14	TURF-AREA CRITICAL	CAM1,CAM4	>20	-	
15		CAM2,CAM3	>20	-	
16	FOOTPATH CLEAR	CAM1,CAM2,CAM3,CAM4	-	-	ZEEBRA_CROSSING
17	FOOTPATH MODERATE	CAM1,CAM4	>10	DRY-LEAVES,DRIED-TWIGS,PALM-FROND	
18		CAM2,CAM3	>20		
19	FOOTPATH CRITICAL	CAM1,CAM4	>10	-	
20		CAM2,CAM3	>10	-	
21	DIC CLEAR	CAM1,CAM2,CAM3,CAM4	-	-	-
22	DIC MODERATE	CAM1,CAM4	>20	-	
23		CAM2,CAM3	>15	-	
24	DIC CRITICAL	CAM1,CAM4	>20	-	
25		CAM2,CAM3	>20	-	
26	BS_PILLARS	CAM1,CAM2,CAM3,CAM4	>70	-	-
27	CHAIRS	CAM1,CAM2,CAM3,CAM4	>70	-	-
28	LITTER-BIN CLEAR	CAM1,CAM2,CAM3,CAM4		-	-
29	LITTER-BIN MODERATE	CAM1,CAM2,CAM3,CAM4	>20	-	-
30	BUS-STOP CLEAR	CAM1,CAM2,CAM3,CAM4	>70	BS_PILLARS, CHAIRS	-
31	BUS-STOP MODERATE	CAM1,CAM2,CAM3,CAM4	>70	BS_PILLARS, CHAIRS	-
32	BUS-STOP CRITICAL	CAM1,CAM2,CAM3,CAM4	>70	BS_PILLARS, CHAIRS	-
33	LANE-CLOSED	CAM1,CAM2,CAM3,CAM4	>10	-	-
34	ROAD	CAM1,CAM2,CAM3,CAM4	>70	-	-
35	DIVIDER_GATE	CAM1,CAM2,CAM3,CAM5	>70	-	-
36	ZEEBRA_CROSSING	CAM1,CAM2,CAM3,CAM6	>70	-	-
37	BARRY_GUARD	CAM1,CAM2,CAM3,CAM7	>70	-	-
38	PLANTING	CAM1,CAM2,CAM3,CAM8	>70	-	-
39	CONSTRUCTION_WORK	CAM1,CAM2,CAM3,CAM9	>70	-	-

Fig. 11

1200

Assets - Condition for Night (6pm to 7am)					
SI NO	Night Assets	Camera	Prediction Confidence Threshold	Condition for "Presence"	Condition for "Absence"
1	ROAD-KERB CLEAR	CAM1,CAM2,CAM3,CAM4	-	-	-
2	ROAD-KERB MODERATE	CAM1,CAM2,CAM3,CAM4	>20	RK-LOW-DRY-LEAVES>0.90 or RK-MEDIUM-DRY-LEAVES>0.60 or RK-SEVERE-DRY-LEAVES>0.60	-
3	ROAD-KERB CRITIACL	CAM1,CAM2,CAM3,CAM4	>40	RK-LOW-DRY-LEAVES>0.90 or RK-MEDIUM-DRY-LEAVES>0.60 or RK-SEVERE-DRY-LEAVES>0.60	-
4	SCUPPER-HOLE CLEAR	-	-	-	-
5	SCUPPER-HOLE MODERATE	-	-	-	-
6		-	-	-	-
7	SCUPPER-HOLE CRITICAL	-	-	-	-
8		-	-	-	-
9	TURF-AREA CLEAR	CAM1,CAM2,CAM3,CAM4	>50	-	
10	TURF-AREA MODERATE	CAM1CAM2,CAM3	-	(MEDIUM-DRY-LEAVES >0.50 or HIGH-DRY-LEAVES>0.50) and (TA-LOW-DRY-LEAVES>0.50 or TA-HIGH-DRY-LEAVES>0.50 or TA-MEDIUM-DRY-LEAVES>0.50 or TA-SEVERE-DRY-LEAVES>0.40)	
11					
12					
13					
14	TURF-AREA CRITICAL	CAM1,CAM2,CAM3,CAM4	-	(SEVERE-DRY-LEAVES>0.20 or HIGH-DRY-LEAVES>0.20 or MEDIUM-DRY-LEAVES>0.50) and (TA-LOW-DRY-LEAVES > 0.92 and (TA-HIGH-DRY-LEAVES > 0.50 or TA-MEDIUM-DRY-LEAVES > 0.50))	
15					
16	FOOTPATH CLEAR	CAM1,CAM2,CAM3,CAM4	>50	-	
17	FOOTPATH MODERATE	CAM1,CAM2,CAM3,CAM4	>50		
18		CAM1,CAM2,CAM3,CAM4	>50		
19	FOOTPATH CRITICAL	CAM1,CAM2,CAM3,CAM4	>50	-	
20		CAM1,CAM2,CAM3,CAM4	>50	-	
21	DIC CLEAR	CAM1,CAM2,CAM3,CAM4	>50	-	
22	DIC MODERATE	CAM1,CAM2,CAM3,CAM4	>50	-	
23		CAM1,CAM2,CAM3,CAM4	>50	-	-
24	DIC CRITICAL	CAM1,CAM2,CAM3,CAM4	>50	-	
25		CAM1,CAM2,CAM3,CAM4	>50	-	
26	BS_PILLARS	-	-	-	-
27	CHAIRS	-	-	-	-
28	LITTER-BIN CLEAR	-	-	-	-
29	LITTER-BIN MODERATE	-	-	-	-
30	BUS-STOP CLEAR	-	-	-	-
31	BUS-STOP MODERATE	-	-	-	-
32	BUS-STOP CRITICAL	-	-	-	-
33	LANE-CLOSED	-	-	-	-
34	ROAD	CAM1,CAM2,CAM3,CAM4	>90	-	-
35	DIVIDER_GATE	CAM1,CAM2,CAM3,CAM4	>90	-	-
36	ZEEBRA_CROSSING	CAM1,CAM2,CAM3,CAM4	>90	-	-
37	BARRY_GUARD	CAM1,CAM2,CAM3,CAM4	>90	-	-
38	PLANTING	CAM1,CAM2,CAM3,CAM4	>90	-	-
39	CONSTRUCTION_WORK	CAM1,CAM2,CAM3,CAM4	>90	-	-

Fig. 12

1300

Lapses - Condition for Day (7am to 6pm)				
SI NO	**Lapses**	**Condition**		**Prediction Confidence Threshold**
1	PLASTIC-WRAPPER	Inside Assets	TURF-AREA, FOOTPATH	>40
2	PACKAGING		TURF-AREA, FOOTPATH	>40
3	MASK		TURF-AREA, FOOTPATH	>40
4	TISSUE-PAPER		TURF-AREA, FOOTPATH	>40
5	DEBRIS	Inside Assets	TURF-AREA, FOOTPATH	>40
6	METAL-CAN		TURF-AREA, FOOTPATH	>40
7	PLASTIC-GLASS-BOTTLE		TURF-AREA, FOOTPATH	>40
8	CARDBOARD		TURF-AREA, FOOTPATH	>40
9	PALM-FRONDS	Inside Assets	TURF-AREA, FOOTPATH	>15
10	TREE-BRANCHES		TURF-AREA, FOOTPATH	>15
11	DRIED-TWIGS		TURF-AREA, FOOTPATH	>15
12	HIGH-DRY-LEAVES		TURF-AREA, FOOTPATH	>15
13	OTHERS		TURF-AREA, FOOTPATH	>15
14	SEVERE-DRY-LEAVES		TURF-AREA, FOOTPATH	>15
15	LOW-DRY-LEAVES		TURF-AREA, FOOTPATH	>15
16	MEDIUM-DRY-LEAVES		TURF-AREA, FOOTPATH	>15
17	CIGARETTE-BUTTS	Inside Assets	TURF-AREA, FOOTPATH	>40
18	SILT-DEPOSITION		TURF-AREA, FOOTPATH	>40
19	OVERGROWN-VEGETATIO		TURF-AREA, FOOTPATH	>40

Fig. 13

1400

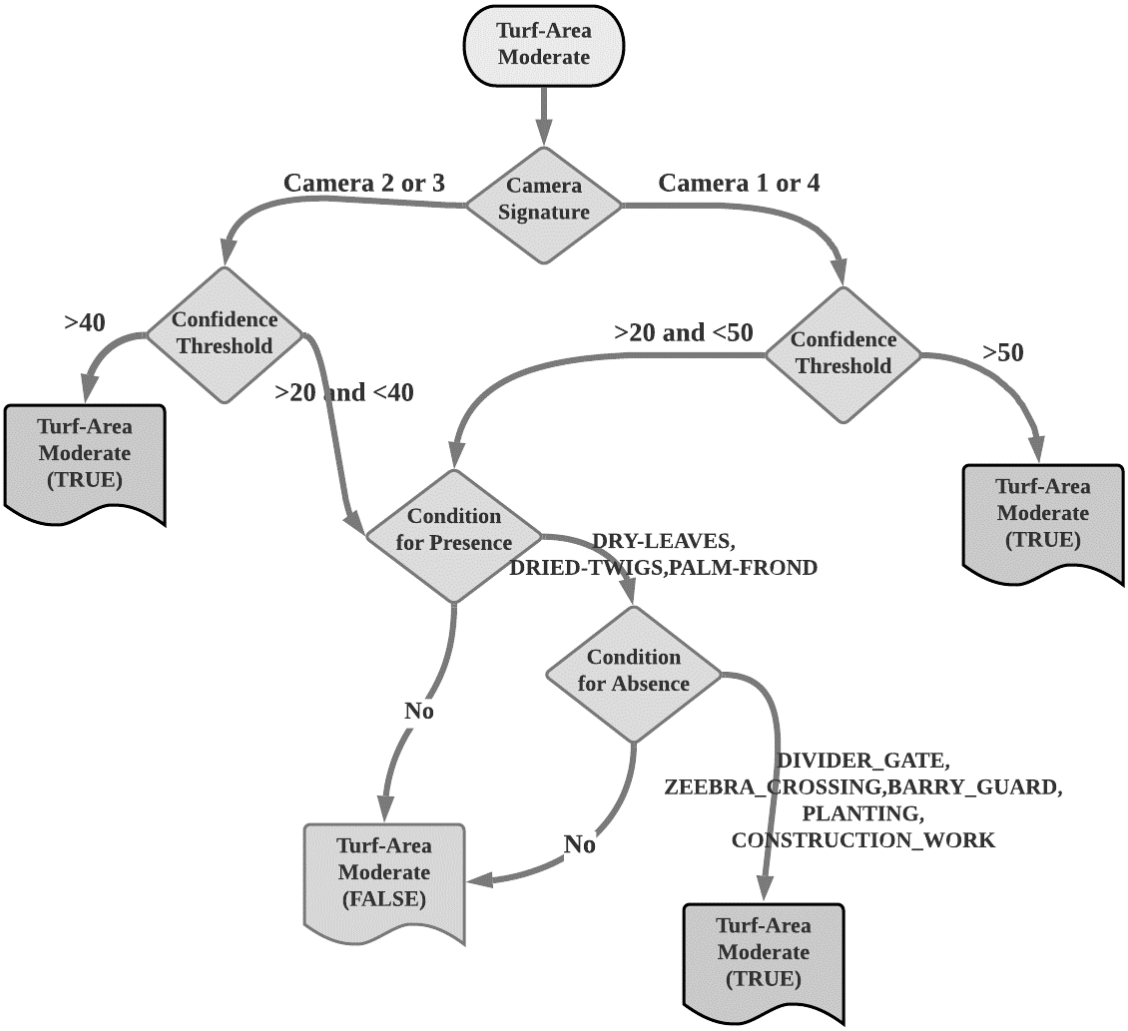

Turf-Area Moderate
Camera Signature
Camera 2 or 3
Camera 1 or 4
Confidence Threshold
>40
>20 and <40
Turf-Area Moderate (TRUE)
Confidence Threshold
>20 and <50
>50
Turf-Area Moderate (TRUE)
Condition for Presence
DRY-LEAVES, DRIED-TWIGS,PALM-FROND
No
Condition for Absence
DIVIDER_GATE, ZEEBRA_CROSSING,BARRY_GUARD, PLANTING, CONSTRUCTION_WORK
No
Turf-Area Moderate (FALSE)
Turf-Area Moderate (TRUE)

Fig. 14

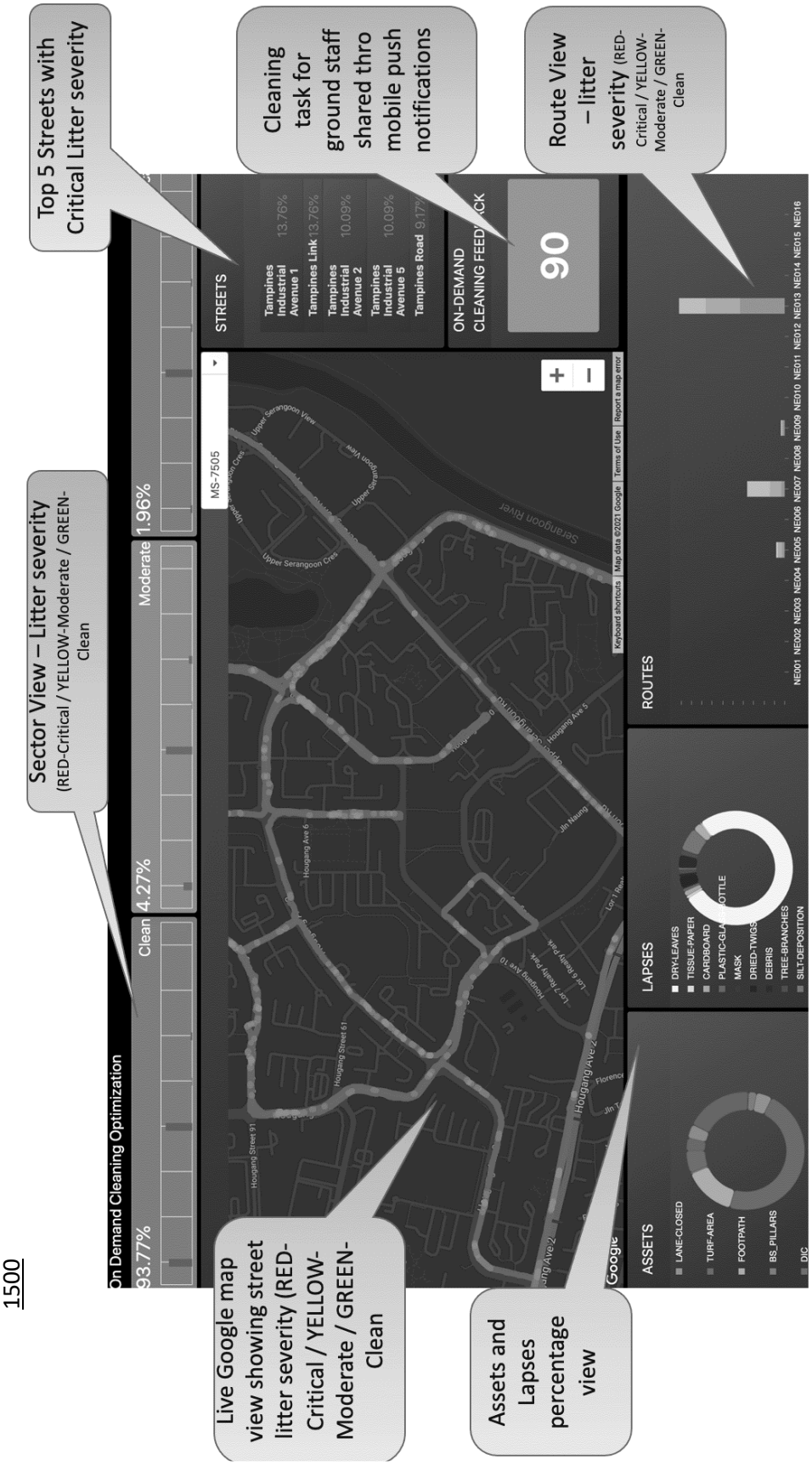

1500
Top 5 Streets with Critical Litter severity
Sector View – Litter severity (RED-Critical / YELLOW-Moderate / GREEN-Clean
Cleaning task for ground staff shared thro mobile push notifications
Route View – litter severity (RED-Critical / YELLOW-Moderate / GREEN-Clean
Live Google map view showing street litter severity (RED-Critical / YELLOW-Moderate / GREEN-Clean
Assets and Lapses percentage view
On Demand Cleaning Optimization
93.77%
Clean
4.27%
Moderate
1.96%
STREETS
Tampines Industrial Avenue 1 13.76%
Tampines Link 13.76%
Tampines Industrial Avenue 2 10.09%
Tampines Industrial Avenue 5 10.09%
Tampines Road 9.17%
ON-DEMAND CLEANING FEEDBACK
90
MS-7505
Serangoon River
Upper Serangoon Crescent
Hougang Avenue 6
Hougang Street 61
Hougang Street 91
Hougang Avenue 2
Hougang Avenue 5
Jln Hwang
Keyboard shortcuts
Map data ©2021 Google
Terms of Use
Report a map error
ROUTES
NE001 NE002 NE003 NE004 NE005 NE006 NE007 NE008 NE009 NE010 NE011 NE012 NE013 NE014 NE015 NE016
LAPSES
DRY-LEAVES
TISSUE-PAPER
CARDBOARD
PLASTIC-GLASS BOTTLE
MASK
DRIED-TWIGS
DEBRIS
TREE-BRANCHES
SILT-DEPOSITION
ASSETS
LANE-CLOSED
TURF-AREA
FOOTPATH
BS_PILLARS
DIC

Fig. 15

1600

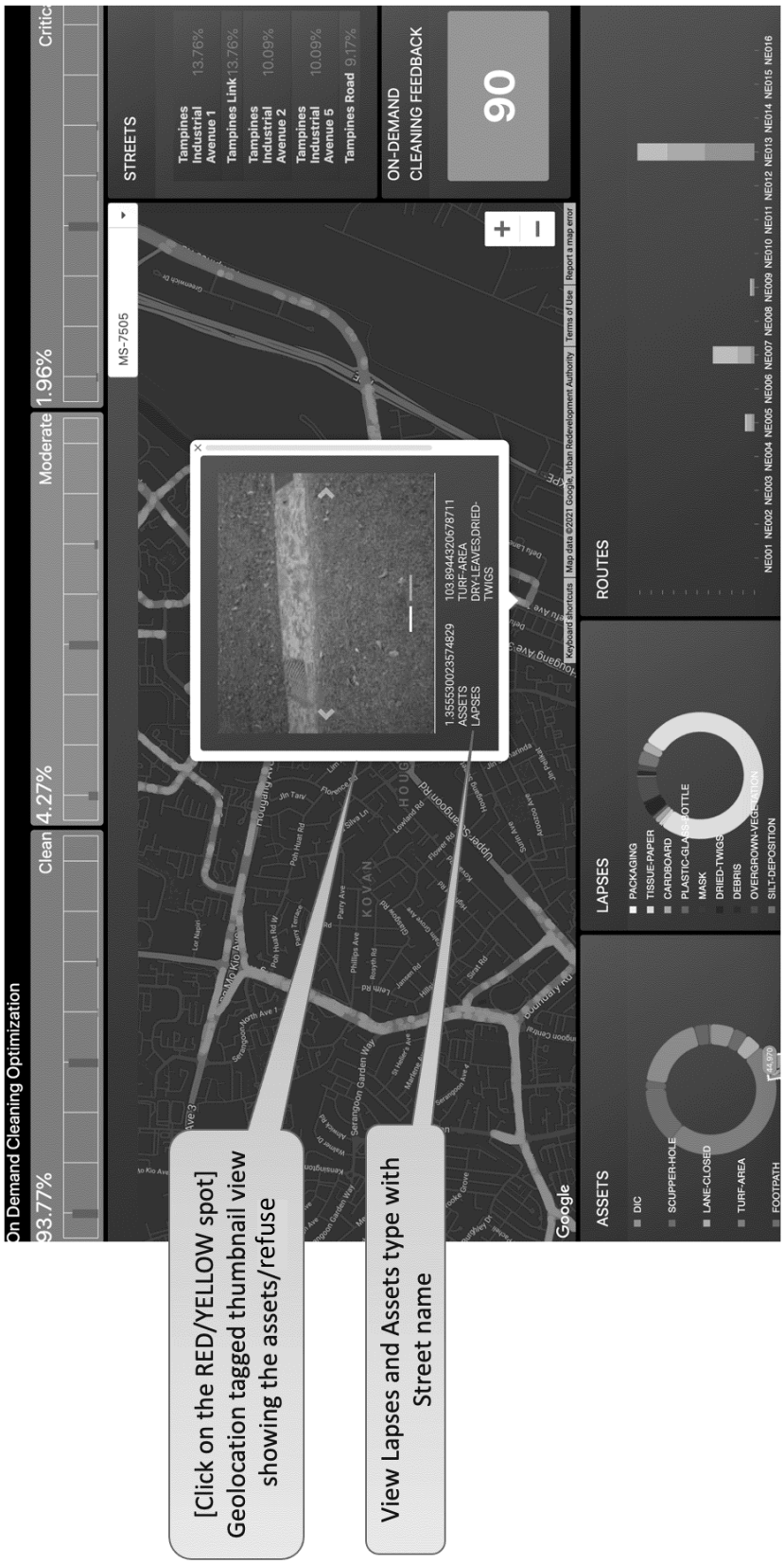

On Demand Cleaning Optimization
93.77%
Clean
4.27%
Moderate
1.96%
Critic
MS-7505
STREETS
Tampines Industrial Avenue 1 13.76%
Tampines Link 13.76%
Tampines Industrial Avenue 2 10.09%
Tampines Industrial Avenue 5 10.09%
Tampines Road 9.17%
ON-DEMAND CLEANING FEEDBACK
90
1.3555300235748 29
ASSETS
LAPSES
103.8944320678711
TURF-AREA
DRY-LEAVES,DRIED-TWIGS
ASSETS
DIC
SCUPPER-HOLE
LANE-CLOSED
TURF-AREA
FOOTPATH
LAPSES
PACKAGING
TISSUE-PAPER
CARDBOARD
PLASTIC-GLASS-BOTTLE
MASK
DRIED-TWIGS
DEBRIS
OVERGROWN-VEGETATION
SILT-DEPOSITION
ROUTES
NE001 NE002 NE003 NE004 NE005 NE006 NE007 NE008 NE009 NE010 NE011 NE012 NE013 NE014 NE015 NE016
Google
[Click on the RED/YELLOW spot] Geolocation tagged thumbnail view showing the assets/refuse
View Lapses and Assets type with Street name

Fig. 16

1702



Fig. 17A

1704



Fig. 17B

1800

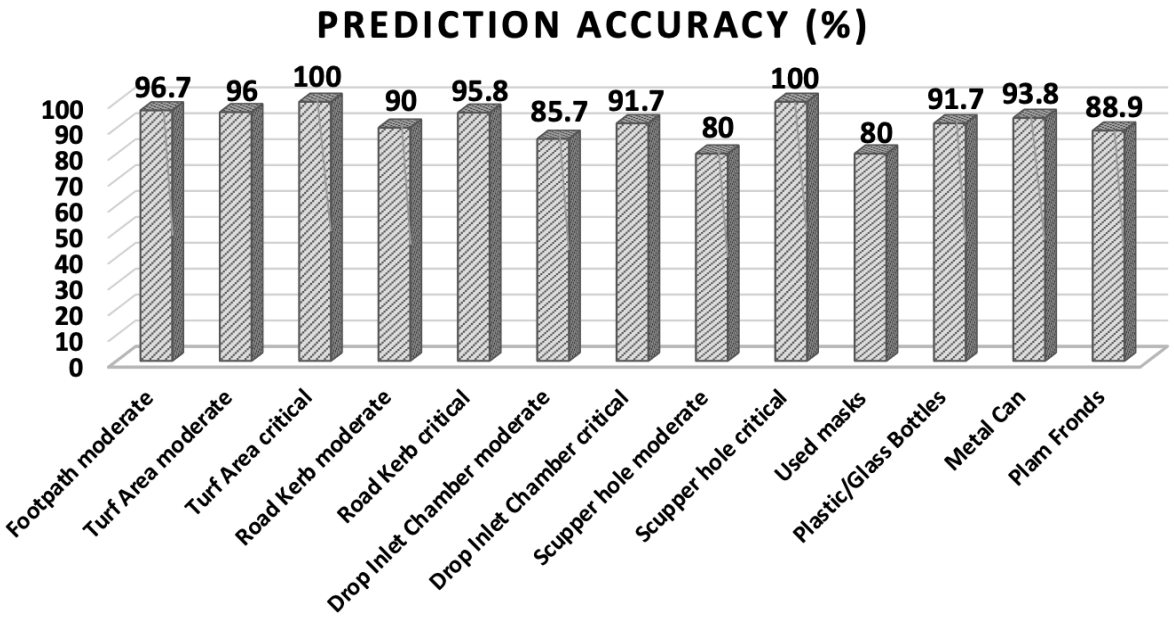

PREDICTION ACCURACY (%)
100
90
80
70
60
50
40
30
20
10
0
96.7
96
100
90
95.8
85.7
91.7
80
100
80
91.7
93.8
88.9
Footpath moderate
Turf Area moderate
Turf Area critical
Road Kerb moderate
Road Kerb critical
Drop Inlet Chamber moderate
Drop Inlet Chamber critical
Scupper hole moderate
Scupper hole critical
Used masks
Plastic/Glass Bottles
Metal Can
Plam Fronds

Fig. 18