Index

ABC. See Activity-based costing (ABC)
Acceptable quality level (AQL), 218
Acceptance sampling, 216, 218, 219
Activity-based costing (ABC), 164
Affinity diagram, 231
Age-based preventive maintenance, 170
Aggregate planning, 141–142
AM. See Autonomous maintenance (AM)
American customer satisfaction index (ACSI), 16
American Society of Quality (ASQ), 179
Anodes and anolyte system, 118–120
Antichip primer coating, 123–125
AQL. See Acceptable quality level (AQL)
Arc welding
characteristics, 83–84
principles, 81–83
ASCI. See American customer satisfaction index (ACSI)
ASQ. See American Society of Quality (ASQ)
Assemble to order (ATO), characteristics of, 151–153
Assemble to stock (ATS), characteristics of, 151–153
Assembly joining quality concept of, 188–189
laser beam welding (LBW), 191–192
RSW quality assessment, 189–191
Auto Industry Action Group in 1993, 212
Automakers, 214
capacity of, 10–11
global manufacturing, 3–5
performance of
ASCI, 16
corporate case studies, 23–24
total company performance, 14–15
strategy
corporate case studies, 23–24
low-cost, 22
management, 23
manufacturing, 24–26
product differentiation, 22
Automotive industry
business strategy
automakers’ strategy, 22–26
capacity of, 10–11
global manufacturing, 3–5
quality and J.D. Power indexes, 11–12
strategy
corporate case studies, 23–24
low-cost, 22
management, 23
manufacturing, 24–26
product differentiation, 22
Automotive manufacturing operations
characteristics
types, 58–60
vehicle assembly, 60–61
competition and assessment
labor utilization efficiency, 12–14
performance of automakers, 14–16
quality and J.D. Power indexes, 11–12
operations
characteristics
types, 58–60
vehicle assembly, 60–61
competition and assessment
labor utilization efficiency, 12–14
performance of automakers, 14–16
quality and J.D. Power indexes, 11–12
operations
Automotive manufacturing operations
(Cont.)
flow, 32–33
powertrain
engines process, 50–51
high-pressure die casting, 51–52
manual assembly operation, 50–51
transmission, 52–53
sheet metal stamping
hydroforming process, 48–50
overall operation, 46
typical processes, 46–48
system perspective
conversion, 53–54
functional, 54–55
performance, 55–56
subsystems, 56–58
tooling and facilities in, 166
vehicle assembly plant, 31–32
body framing, 34–37
general assembly, 41–46
paint operation, 37–41
process flow of, 33–34
top view, 31, 32
Automotive market
characteristics, 5–7
competition
five-force model, 9–10
four competitive attributes, 7–9
manufacturing capacity, 10–11
global manufacturing
automakers, 3–5
by region, 1–3
Autonomous maintenance (AM), 172

Base coat, 40
Batch processing, 243–244
Beam parameter product (BPP), 75
Best in Ford (BIF), 224
Bill of material (BOM), 143
BIW. See Body in white (BIW)
Block-based model, 170
Body (weld) framing
aim, 34
BIW, 35–36
elements, 34
incoming materials, 35
unibody architecture, 35–37
workstation, 34, 35
Body in white (BIW), 35–36
Body paint quality, 192–195
BOM. See Bill of material (BOM)
Bottleneck analysis, 244
buffer status, analysis of, 250–252
stand alone availability (SAA), 246–250
theory of constraints (TOC), 245–246
Buffer status, analysis of, 250–252
Capability constraints, of manufacturing system, 225
Cap wear correction, 73–74
Cause–effect diagram, 231
China's automotive industry, 2
Clinching, 91–92
CMMs. See Coordinate measurement machines (CMMs)
C- More, 157
Collision welding. See Impact welding
Color coat and clear coat processes, 125–129
Color coding, for status of issues, 240–241
Complexity reduction, 242–243
Consumer Reports Magazine (CR), 15–16
Continuous improvement approach
problem solving process, 227–230
structured brainstorming approaches, 230–233
Conventional engineering practice, 182
Coordinate measurement machines (CMMs), 204–206
Corrective maintenance, 168
Correlation analysis, 256–257
Cost elements, 162
Cream coat, 111
Customer demands, production control based on
ATS and ATO, characteristics of, 151–153
planning and execution, types of, 150–151

Define, measure, analyze, improve, and control (DMAIC), 227–229

Depreciation
equipment, 164–166
of tooling and facilities, 166–167

Design for quality, 181–184

Design For Six Sigma (DFSS) method, 182

Development of Advanced Technologies and Systems for Controlling Dimensional Variation in Automobile Body Manufacturing, 256

Dimensional quality inspections
in-line and offline inspections, 206–208
quality inspections in manufacturing, 204–206
management
dimensional quality inspections, 204–208
functional build in tryouts, 208–210
metrology review, 200–204
of vehicle, 180

Direct labor cost, 163

Dispersion-strengthened copper (DSC), 73–74

DMAIC. See Define, measure, analyze, improve, and control (DMAIC)

Downtime analysis, 239–241
Downtime Problem Solving Form, 239–240
Downtime recording matrix, 239
Downtime tracking, 239
Drawn-arc stud welding, 85–87
Dynamic repeatability test, 207

E-coat. See Electrodeposition coating (E-coat)

Economic analysis of equipment
depreciation of tooling and facilities, 166–167
economic life of equipment, 167
equipment depreciation, 164–166
Economic life of equipment, 167

Electrode caps, 72–73

Electrodeposition coating (E-coat), 39
paint cure process, 135–136
quality, issues and possible causes, 193
vehicle paint process
challenge, 116
elements, 110
facilities, 116–120
parameters, 113–116
principle, 111–113
process flow, 111
rinsing, 111

Enterprise resource planning (ERP), 143–145

Equipment maintenance management strategies
cost and risk of maintenance, 170–171
maintenance management, types of, 168–169
total productive maintenance (TPM), 172

ERP. See Enterprise resource planning (ERP)

European Union (EU), 2

Execution, types of, 150–151

Factory Information System, 157

Failure mode effect and analysis (FMEA), 171

FBC. See Function-based costing (FBC)

Final audits, assessment based on, 198–200
First-time compliance (FTC), 198
5-whys, 232–233

Flows, automotive
manufacturing operations engineering activities, 33
incoming materials and parts, 33
information, 32
Flows, automotive manufacturing operations (Cont.)
people and operations, 33
vehicle assembly, 33–34
FMEA. See Failure mode effect and analysis (FMEA)
Force field analysis, 232
Ford Fusion, 242
Four market competitive attributes, 7–9
Friction stir spot welding (FSSW), 88
Friction stir welding (FSW), 87–89
FSSW. See Friction stir spot welding (FSSW)
FSW. See Friction stir welding (FSW)
FTC. See First-time compliance (FTC)
Functional build (FB) in tryouts, 208–210
Function-based costing (FBC), 164
Gage repeatability and reproducibility (GR&R) test, 202–204
Gas metal arc welding (GMAW), 81
General and administrative (G&A) cost, 164
General assembly (GA)
characteristics, 44–46
chassis lines, 43–44
final stage, 44
process flow, 41–43
trim lines, 43
General Motors (GM), 237
Generic business strategy
competitive advantages, 20
cost leadership strategy, 19–20
German automobile industry, 212
Global automotive manufacturing automakers
countries with high vehicle production, 4
main suppliers of vehicle parts, 5
top ten, 3
by region, 1–3
GM. See General Motors (GM)
Goldratt’s principle, 245
Governing metal thickness (GMT), 66
GR&R test. See Gage repeatability and reproducibility (GR&R) test
Hours per vehicle (HPV), 12–14
Hydroforming process
sheet panel, 50
sheet process, 48, 49
space frame, 48
tube, 48, 49
Hyundai, 147
Impact welding, 89–90
Indirect labor cost, 163
Initial Quality Survey (IQS), 11
Initial Sample Inspection Report (ISIR), 212
In-line and offline inspections, 206–208
In-line measurement sensors, 208
Interfacial fracture (IF), 69
ISIR. See Initial Sample Inspection Report (ISIR)
Japan, 3
J.D. Power indexes, 11–12
Joining processes, for body assembly
arc welding
characteristics, 83–84
principles, 81–83
drawn-arc stud welding, 85–87
friction stir welding, 87–89
impact welding, 89–90
laser beam welding
advantages, 77–78
challenges to, 78–81
characteristics, 75–77
principle, 74–75
mechanical and bonding
adhesive, 92–93
clinching, 91–92
self-piercing riveting, 90–91
projection stud welding, 84–85
resistance spot welding
characteristics, 67–71
equipment, 71–74
principle, 65–67
selection
advancement trends, 95–96
comparison, 96–97
technologies, 98
Joint configurations for dimensional quality, consideration of, 184
Joule’s first law, 65
Just in time and inventory, 147–148
Kanban approach, 146
Key performance indicators (KPIs)
manufacturing operational performance, 153–155
overall equipment effectiveness, 158–160
production throughput measurement, 156–158
Knowledge-based system technology, 254
Korea, 3
Laser beam welding (LBW), 191–192
advancements, 80–81
advantages, 77–78
characteristics, 75–77
principle, 74–75
vs. RSW
initial investment, 78
welding zinc-coated steels, 79–80
Liquid-applied sound deadener (LASD), 137
Lot tolerance percent defective (LTPD), 218
Maintenance effectiveness
system performance, measured by, 172–173
total cost, measured by, 173–175
Maintenance management, types of, 168–169
Maintenance scheduling, 170
Manufacturing costs, 160–161, 161
operating costs, 161–164
overhead costs, 164
Manufacturing operational performance, 153–155
Manufacturing planning approaches, 141
Manufacturing quality assurance
overall considerations for manufacturing quality, 184–185
quality inspections and audits, 186–187
total quality management, 187–188
Manufacturing Quality Control (MQC), 212
Manufacturing system
buffer in, 250
capability constraints of, 225
variables in, 185
Mass customization, 150
Master production schedule (MPS), 142
Material requirements planning (MRP), 143
Mean time between failures (MTBF), 173
Mean time to repair (MTTR), 173
Measurement accuracy, 201
Mechanical joining and bonding
adhesive, 93–94
applications, 92–93
design considerations, 93–94
process consideration, 94–95
clinching, 91–92
self-piercing riveting, 90–91
Median frequency direct current (MFDC), 69–70
Metrology review
fundamental concepts, 200–201
repeatability and reproducibility, 202–204
Michael Porter’s five-force model, 9–10
Mizushima Assembly Plant, 44–45
Modular ERP system, 144
Monopolistic competition, 5–7
MPS. See Master production schedule (MPS)
MQC. See Manufacturing Quality Control (MQC)
MRP. See Material requirements planning (MRP)
Index

MRP II, 143
  functions of, 144
MTBF. See Mean time between failures (MTBF)
MTTR. See Mean time to repair (MTTR)
Multivariable correlation analysis, 256–258

National Highway Traffic Safety Administration (NHTSA), 181
NHTSA. See National Highway Traffic Safety Administration (NHTSA)
Nominal group technique, 230–231
Normal distribution of quality data, 185
North America (NA), 2

OCC. See Operating Characteristics Curve (OCC)
OEE. See Overall equipment effectiveness (OEE)
Oligopoly market, 5–7
One-page downtime problem solving form, 240
Operating Characteristics Curve (OCC), 217, 218
Operating costs, 161–164
Operational performance improvement bottleneck analysis, 244
  buffer status, analysis of, 250–252
  stand alone availability, 246–250
  theory of constraints (TOC), 245–246
  performance improvement
  continuous improvement, approaches of, 227–233
  performance continuous improvement, 223–227
  value stream analysis, 233–235
  production throughput improvement
  production complexity reduction, 242–244
  production downtime analysis, 239–242
  production throughput analysis, 235–238
  variation reduction
  characteristics of, 254–256
  concept of, 252–254
  multivariable correlation analysis, 256–258
  quality concern on parallel lines, 258–262
Operational performance, manufacturing
  basic assessment of, 153–154
  perspective on, 155
Operations management, 223
Overall equipment effectiveness (OEE), 158–160, 172
Overhead costs, 164
Paint cure process
  E-coat, 135–136
  parameters, 133–135
  wet process, 136
Paint operation. See also Vehicle
  paint process
  main processes, 38–41
  overall flow, 37–38
  robotic spray, 40, 41
Paint quality issues, 194
Paint spray processes
  color coat and clear coat processes, 125–129
  equipment and facilities
    paint booth, 131–133
    spray applicators, 129–130
  materials, 120–122
  pretreatment, 122–123
  primer application, 123–125
Parallel lines, quality concern on
  data distribution of parallel lines, 258–259
  parallel line variation, 260–262
  variation of two lines
    with different means, 260
    with different variances, 259–260
Pareto analysis, 228
Pareto chart, 229, 238, 255
Pareto’s principle, 256
Part quality management, 210–211
  production part quality assurance, 211–215
  quality monitoring and sampling, 215–219
PDCA. See Plan-do-check-act (PDCA)
Perceived quality, 180
Performance continuous improvement
  employee participation, 224–227
  mindset of continuous improvement, 223–224
Performance improvement
  continuous improvement, approaches of, 227–233
  performance continuous improvement, 223–227
  value stream analysis, 233–235
Phosphate processes, 106
  after spray, 108
  conditioning stages, 108
  deionized water rise, 108–109
  parameters, 109–110
  phases, 107
Phosphate quality, issues and possible causes, 193
Phosphate stage, 38–39
Plan–do–check–act (PDCA), 229–230
Plan-driven pull-based production execution, 149
Planning, types of, 150–151
Polycrystalline cubic boron nitride (PCBN), 88
Polyurethane (PUR) foam application, 139
Powertrain (PT) manufacturing
  engines process, 50–51
  high-pressure die casting, 51–52
  manual assembly operation, 50–51
  transmission, 52–53
Predictive maintenance, 169
Pre-emptive maintenance, 171
Preventive maintenance, 168, 170
Problem solving process, 227–230
Process Approach of ISO/TS 16949, 212
Product characteristics, 183
Product development (PD), 182
Production complexity reduction
  batch processing, 243–244
  reduction of vehicle configurations, 242–243
Production control based on customer demands
  ATS and ATO, characteristics of, 151–153
  planning and execution, types of, 150–151
Production downtime analysis
  downtime analysis, 239–241
  downtime tracking, 239
  evaluation and prioritization, 241–242
Production operations management
  equipment maintenance management
    maintenance effectiveness, 172–175
    strategies, 168–172
  key performance indicators
    manufacturing operational performance, 153–155
    overall equipment effectiveness, 158–160
    production throughput measurement, 156–158
  manufacturing costs, 160–161
    economic analysis of equipment, 164–167
    types of, 161–164
  production planning and execution approaches, 141–145
    production control based on customer demands, 150–153
    push-based and pull-based execution, 145–150
Production Part Approval Process (PPAP)
  principle of, 211–213
  requirements of, 213–215
Production part quality assurance
  principle of, 211–213
  requirements of, 213–215
Production planning approach, 141
aggregate planning, 141–142
enterprise resource planning, 143–145
master production schedule, 142
material requirements planning, 143
Production throughput analysis
case study of throughput improvement, 237–238
influencing factors to throughput, 235–237
Production throughput improvement
production complexity reduction, 242–244
production downtime analysis, 239–242
production throughput analysis, 235–238
Production throughput measurement,
156–158
other influencing factors, 158
throughput monitoring, 156–158
Projection stud welding, 84–85
Push-based and pull-based execution
characteristics of, 149–150
distinction of, 145–147
just in time and inventory, 147–148
work in process (WIP), 148–149
Quality
acceptance sampling, 216
data, normal distribution of, 185
design for, 181–184
inspection measurements, objectives
and quantity of, 211
inspections and audits, 186–187
methodologies, 183
monitoring and sampling, 215–219
discussion of sampling applications,
217–219
principle of sampling plans, 215–217
recognition of, 179–181
Quality concern on parallel lines
data distribution of parallel lines, 258–259
parallel line variation, 260–262
variation of two lines
with different means, 260
with different variances, 259–260
Quality management for vehicle assembly
design for quality, 181–184
dimensional quality management
dimensional quality inspections, 204–208
functional build in tryouts, 208–210
metrology review, 200–204
manufacturing quality assurance, 184–188
part quality management, 210–211
production part quality assurance, 211–215
quality monitoring and sampling, 215–219
recognition of quality, 179–181
vehicle manufacturing quality
assembly joining quality, 188–192
body paint quality, 192–195
vehicle final quality audit, 195–200
Radar chart of overall system
performance, 154
Reactive maintenance, repair types and
failure risks of, 171
Reduction of vehicle configurations,
242–243
Remote laser welding (RLW), advantage
of, 77–78
Repeatability, 202–204, 207
Reproducibility, 202–204
Resistance projection welding (RPW),
84–85
Resistance spot welding (RSW)
characteristics
current and force controls, 70–71
process parameters, 67–68
steel and aluminum welding, 68–70
equipment
cap wear correction, 73–74
electrode caps, 72–73
weld guns, 71–72
Index

joint, 188
vs. LBW
  initial investment, 78
welding zinc-coated steels, 79–80
principle
electrical resistance, 66
electrode force vs., 66–67
heat generated, 65
Joule’s first law, 65
quality assessment, 189–191
RoDip, 116–117
RPW. See Resistance projection welding (RPW)
RSW. See Resistance spot welding (RSW)
SAA. See Stand alone availability (SAA)
Safety quality, 181
SAJPH. See Stand-alone JPH (SAJPH)
Sampling applications, 217–219
Sampling plans, principle of, 215–217
Scan system, 208
Sheet metal stamping
  hydroforming process
    sheet panel, 50
    sheet process, 48, 49
    space frame, 48
    tube, 48, 49
    overall operation, 46
typical processes, 46–48
Skillset radar chart for production teams, 154
SPC. See Statistical process control (SPC)
Stand alone availability (SAA)
distinction of, 246–247
stand-alone JPH, 248–250
Stand-alone JPH (SAJPH), 248–250
Statistical process control (SPC), 228
Steel and aluminum welding, 68–70
Structured brainstorming approaches, 230–233
System performance, measured by, 172–173
Technical cost modeling (TCM), 164
Theory of constraints (TOC), 245–246
Three-level business strategy
corporate strategy, 17
operation strategy, 18
stakeholders and interests, 17
UK national manufacturing strategy, 18
Throughput monitoring, 156–158
TOC. See Theory of constraints (TOC)
Tooling and facilities, depreciation of, 166–167
Total company performance (TCP), 14–15
Total cost, measured by, 173–175
Total productive maintenance (TPM), 172
Total quality management (TQM), 187–188
Toyota, 212
TPM. See Total productive maintenance (TPM)
TQM. See Total quality management (TQM)
Trend chart, 255
Turnovers (TOs) rate, 118
Ultrahigh strength steel (UHSS), 68–69, 189, 190
Value added time (VAT), 233, 234
Value stream analysis, 233–235
Value stream mapping (VSM), 233–235
Vaporizing foil actuator welding (VFAW), 89–90
Variables in manufacturing systems, 185
Variation reduction
  characteristics of, 254–256
  concept of, 252–254
  multivariable correlation analysis, 256–258
  quality concern on parallel lines, 258–262
Variation Reduction Advisor, 254
VAT. See Value added time (VAT)
Vehicle assembly plant, 31–32
  body (weld) framing
    aim, 34
    BIW, 35–36
Vehicle assembly plant (Cont.)
  elements, 34
  incoming materials, 35
  unibody architecture, 35–37
  workstation, 34, 35
general assembly
  characteristics, 44–46
  chassis lines, 43–44
  final stage, 44
  process flow, 41–43
  trim lines, 43
paint operation
  main processes, 38–41
  overall flow, 37–38
  process flow of, 33–34
  top view, 31, 32
Vehicle body framing. See Body (weld) framing
Vehicle configurations, reduction of, 242–243
Vehicle crashworthiness quality, 181
Vehicle door, check points on, 206
Vehicle final quality audit
  assessment based on final audits, 198–200
  final inspections of vehicles, 195–198
Vehicle manufacturing quality
  assembly joining quality, 188–192
  body paint quality, 192–195
  vehicle final quality audit, 195–200
Vehicle manufacturing system, 245
Vehicle paint process
  clean and phosphate processes, 106
  after spray, 108
  conditioning stages, 108
  deionized water rise, 108–109
  parameters, 109–110
  phases, 107
  cure process
  considerations, 135–136
  parameters, 133–135
  wet process, 136
  E-coat
Chrome challenge, 116
  elements, 110
  facilities, 116–120
  parameters, 113–116
  principle, 111–113
  process flow, 111
  rinsing, 111
  flow, 105
  layers, 106
nonpainting operations
  PUR foam applications, 139
  sealing operations, 136–139
spray processes
  color coat and clear coat processes, 125–129
  equipment and facilities, 129–133
  materials, 120–122
  pretreatment, 122–123
  primer application, 123–125
Vehicle paint quality, 192
Vehicle production control—pull mode, 146
Vehicle production control—push mode, 145
Vehicle quality, dimensions of, 180
Vehicles, final inspections of, 195–198
Vehicle structural engineering, load path consideration in, 181
VFAW. See Vaporizing foil actuator welding (VFAW)
VSM. See Value stream mapping (VSM)
Weld guns, 71–72
Welding. See Body (weld) framing
Welding zinc-coated steels, 79–80
Well-leveled system, 147
WIP. See Work in process (WIP); Work in progress (WIP)
Work in process (WIP), 145, 148–149
Work in progress (WIP), 250–252
Zinc phosphate, 110
Zirconium oxide coating, 110
About the Author

Dr. Tang is currently a professor at Eastern Michigan University (EMU). Before joining EMU, he was a lead engineering specialist at Fiat Chrysler Automobiles. Dr. Tang has been working in the various areas of automotive assembly since 1993, including manufacturing development for five new vehicle programs and launch supports of seven times at vehicle assembly plants. His technical expertise is in the areas of assembly system development, process planning, tooling development management, lean manufacturing, dimensional quality control, welding, launch support, and project management. Dr. Tang holds a doctorate degree from the University of Michigan—Ann Arbor, a master’s degree, and a bachelor’s degree from Tianjin University, China, all of mechanical engineering. Dr. Tang also earned an MBA degree in industrial management from Baker College. Dr. Tang is a member of Society of Automotive Engineers, Society of Manufacturing Engineering, American Welding Society, and American Society of Mechanical Engineers.