



HAL
open science

CUMULATIVE MANUFACTURING CAPABILITIES: AN EXTENDED MODEL AND NEW EMPIRICAL EVIDENCE

Lucia Avella, Daniel Vazquez-Bustelo, Esteban Fernandez

► **To cite this version:**

Lucia Avella, Daniel Vazquez-Bustelo, Esteban Fernandez. CUMULATIVE MANUFACTURING CAPABILITIES: AN EXTENDED MODEL AND NEW EMPIRICAL EVIDENCE. International Journal of Production Research, 2010, pp.1. 10.1080/00207540903460224 . hal-00561817

HAL Id: hal-00561817

<https://hal.science/hal-00561817>

Submitted on 2 Feb 2011

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



CUMULATIVE MANUFACTURING CAPABILITIES: AN EXTENDED MODEL AND NEW EMPIRICAL EVIDENCE

Journal:	<i>International Journal of Production Research</i>
Manuscript ID:	TPRS-2009-IJPR-0186.R2
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	16-Oct-2009
Complete List of Authors:	Avella, Lucia; University of Oviedo, Business Administration Vazquez-Bustelo, Daniel; University of Oviedo, Business Administration Fernandez, Esteban; University of Oviedo, Business Administration
Keywords:	MANUFACTURING STRATEGY, OPERATIONS STRATEGY, EMPIRICAL STUDY, ENVIRONMENTAL MANAGEMENT, MANUFACTURING MANAGEMENT, PERFORMANCE MEASURES
Keywords (user):	



1
2
3 **CUMULATIVE MANUFACTURING CAPABILITIES: AN EXTENDED MODEL AND NEW EMPIRICAL**
4
5 **EVIDENCE**
6

7 **L. Avella*, D. Vazquez-Bustelo and E. Fernandez**
8

9
10 Department of Business Administration, University of Oviedo, Facultad de Ciencias Económicas y
11 Empresariales, Avda. Cristo s/n, 33071 Oviedo, Spain
12

13
14 **Abstract**
15

16 There has been intense debate in the manufacturing strategy literature on the way in which firms work on
17 different manufacturing capabilities, with two opposing approaches considered –the *trade-off* model and the *sand*
18 *cone* model. Analysis of these models has essentially been based on study of the links amongst four classic
19 manufacturing capabilities (quality, delivery, flexibility and cost efficiency) and has obviated the need to consider
20 environmental protection as an important manufacturing capability. This study analyses the theoretical
21 arguments and the prior empirical evidence on the two models, and proposes and tests an extended *sand cone*
22 model which includes the environmental protection objective alongside the four traditional ones. The research
23 uses structural equation modelling and data from a sample of 274 manufacturers to contribute additional
24 empirical evidence on the existence of cumulative effects amongst manufacturing capabilities. It is observed that
25 the predominant strategic model in these firms is one of multiple, non-incompatible capabilities with cumulative
26 effects according to the following sequence: quality, delivery, flexibility, environmental protection and cost
27 efficiency.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43

44 **Keywords:** manufacturing strategy; manufacturing capabilities; *trade-offs*; *sand cone* model; environmental
45 protection
46
47
48
49
50
51
52
53
54
55
56
57
58

59 *Corresponding author: Email: lavella@uniovi.es
60

CUMULATIVE MANUFACTURING CAPABILITIES: AN EXTENDED MODEL AND NEW EMPIRICAL EVIDENCE

1. INTRODUCTION

In recent decades, there has been intense debate in the manufacturing strategy literature on the way in which firms work on different manufacturing capabilities. Generally speaking, two opposing approaches are considered – the *trade-off* model and the *sand cone* model. Analysis of these models has essentially been based on study of the links amongst the classic manufacturing objectives of quality, delivery, flexibility and cost efficiency and has led to diverging results (Rosenzweig and Easton, 2006).

This study analyses the theoretical arguments and the prior empirical evidence on the two models and offers additional evidence on the existence of cumulative links amongst the four classic manufacturing objectives of quality, delivery, flexibility and cost efficiency.

Moreover, analysis of the links amongst the objectives has generally obviated the need to consider new objectives –such as the environmental protection, that due to their increasing importance (Aragón-Correa *et al.*, 2008) should be taken into account in the analysis of manufacturing strategy.

Environmental aspects have become an essential element in the business strategy of a large number of firms (Angell, 1999) and have led many managers to consider improvements in environmental protection performance as one of their basic priorities. However, although the scientific community has called for the inclusion of the environmental protection in the set of manufacturing objectives (Angell and Klassen, 1999; De Burgos and Céspedes, 2001; Inman, 2002; Kleindorfer *et al.*, 2005), research to date has paid scarce attention to it. This research tries to fill this gap in the manufacturing strategy literature by proposing and testing an extended *sand cone* model which includes the environmental protection objective alongside the four traditional objectives. It therefore adopts an integrated perspective for environmental operations management (Angell and Klassen, 1999), considering the environmental protection as an objective for the production department and not just as an external condition imposed on the firm.

The study is structured as follows. After this introduction, there is a review of the literature on the definition of the manufacturing objectives and the models established for achieving them. On the basis of this review of the literature, the objectives of the study and the hypotheses to be tested are laid down. The research methodology

1
2
3 is then presented and the measurement variables used are tested. Finally, after analysis of the results obtained,
4
5 the main conclusions are drawn and limitations and possible future research lines are mentioned.
6

7 8 **2. BACKGROUND**

9 10 **2.1. Manufacturing objectives**

11 Since the field of manufacturing strategy was first set up, four basic manufacturing objectives have been
12 considered: cost efficiency, quality, flexibility and delivery (Skinner, 1969, 1974; Hayes and Schmenner, 1978;
13
14 Hayes and Wheelwright, 1984; amongst others).
15
16

17 Although the objectives of innovation (Dangayach and Deshmukh, 2001) and service were also considered, they
18 have not been generally accepted in the literature. This is because some components of flexibility, such as
19 change and volume, also promote innovation (De Toni and Tonchia, 1998), and because service can be
20 considered as a component of quality (Garvin, 1983). In recent years, environmental protection has started to be
21 included amongst manufacturing objectives, on the same terms as the four objectives mentioned above
22 (Handfield *et al.*, 1997; Angell and Klassen, 1999).
23
24

25 It cannot be denied that, in the past, environmental protection matters were considered a restriction for the
26 manufacturing area. Therefore, the only link between the environmental protection factor and manufacturing was
27 the installation of control or end-of-process technologies –those which eliminate any waste produced– which, by
28 their very nature, did not require the consideration of environmental protection matters as a production objective
29 (Newman and Hanna, 1996).
30
31

32 But today manufacturing objectives are considered to have an effect on the environmental protection result and
33 vice versa. So, flexibility leads to a reduction in inventories and therefore fewer products are spoilt while fewer
34 resources are used. Also, products can be better adapted to environmental protection needs (Klassen and
35 Angell, 1998). Improved quality stabilizes production processes, eliminating reprocessing tasks and saving
36 energy and resources (Rosenzweig and Roth, 2004). Moreover, quality management systems have synergies
37 with environmental protection management (Kitazawa and Sarkis, 2000). Cost reductions can also be achieved,
38 amongst other actions, through savings in energy and by recycling products (Porter and van der Linde, 1995a,
39 1995b). And a reduction in delivery time not only reduces inventories but also shortens internal product transport
40 time, eliminating the need for repeat consignments (because deliveries are reliable). This too saves energy
41 (Koufteros *et al.*, 2002).
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Environmental protection practices also affect manufacturing objectives. The use of production processes that
4 consume fewer production inputs or less energy and make use of any waste generated helps reduce costs
5 (Shrivastava, 1995a). Ecoefficiency or reduced costs through more efficient use of resources (Gupta and
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Environmental protection practices also affect manufacturing objectives. The use of production processes that consume fewer production inputs or less energy and make use of any waste generated helps reduce costs (Shrivastava, 1995a). Ecoefficiency or reduced costs through more efficient use of resources (Gupta and Sharma, 1996) is based on the premise that any contamination produced by the firm is a symptom of inefficiency. Moreover, environmental protection management practices affect total quality tools and this causes a move towards total quality environmental management (TQEM) (Welford, 1992), to the extent that the ISO 9000:2000 includes environmental protection aspects. Contamination prevention technologies may provide the production flexibility that firms need if they are to offer products that will not come up against environmental protection restrictions. Also, environmental protection practices can be used for adding value to products by reducing delivery time (Newman and Hanna, 1996). Therefore, Angell and Klassen (1999) suggested that, in the long term, the environmental protection objective should be included at the same level as the other manufacturing objectives thus making them endemic in the production process rather than seeing them only as external restrictions. Moreover, in the short term, they recommended that firms should reflect environmental protection aspects in tactical changes while the management should promote their inclusion in the process in the long term. However, few studies have considered the position of production departments regarding this topic and the effects of such considerations on their results.

This study therefore considers the four traditional objectives (cost efficiency, quality, flexibility and delivery) and includes the environmental protection as the fifth objective in testing the prevailing objective model in firms. These five general objectives are broken down into 22 categories (**Table 1**).

Trying to avoid terminological confusion, in this paper, for each manufacturing objective, we use the term “competitive priority” referring to priority granted or emphasis placed to each manufacturing objective (importance). Whereas, we define “manufacturing capability” as the strength or advantage developed regarding the industry average or relative to primary competitors (performance).

INSERT TABLE 1

2.2. Models for improving manufacturing objectives

Most of the literature on manufacturing strategy is based on the model of incompatibilities –or *trade-offs* to use the term devised by Skinner (1969)– amongst its different objectives. This model is based on two basic premises:

a) the factory has many objectives, and b) some objectives are incompatible with others. A *trade-off* means that

1
2
3 preference or priority is given to one manufacturing objective over others. Manufacturing only one product, a
4 factory might pursue different manufacturing objectives but, furthermore, many objectives might arise because a
5 single factory manufactures: a) products that are at different stages of their life cycle, and b) products that meet
6 different market needs. In this last case, this multiplicity reflects the result of manufacturing two or more products
7 in the same factory to meet different objectives. When products, processes, levels of skills and customer
8 requirements are added, the production department tends to increase its size and, especially, to establish
9 different objectives to meet different market needs (Skinner, 1974).

10
11
12 The traditional strategic approach is that the different objectives are incompatible (Hofer and Schendel, 1978),
13 because they consider it is difficult and risky for a firm to try to compete by offering high performance results in all
14 its objectives. Firms that aim to be exceptional in many objectives end up being worse than those which focus
15 their efforts on a single objective. In the manufacturing field, Skinner (1969) proposed that each manufacturing
16 department (factory or strategic manufacturing unit) should focus on one or, at the most, two of the various
17 possible objectives. Skinner (1969) called this explicit, priority objective the 'manufacturing task', although the
18 more usual term is 'competitive priority'. The manufacturing task (or competitive priority) should be maintained
19 over time and indicates to a certain extent that achieving this objective is more important than achieving others.
20 There is thus a synergy effect within the production department, with the actions of the various responsibility
21 centres being oriented in the same direction (Hayes and Schmenner, 1978).

22
23
24 Some researchers move away from the *trade-off* model and defend achieving a balance amongst different
25 objectives. They assume there is a link –not a conflict– between long and short term objectives (Banks and
26 Wheelwright, 1979). Following this argument, Hugel and Anderson (1988) consider that the various objectives
27 can be improved simultaneously because they do not oppose each other and they can be reached in a concerted
28 way. So, based on the experience of Japanese manufacturers, it has been noted that some firms tend to
29 simultaneously achieve acceptable performance levels in the various manufacturing objectives, thus eliminating
30 *trade-offs* (Hayes and Pisano, 1994).

31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000

Certain authors consider that balance amongst objectives can be achieved in a sequential (cumulative) way using the '*sand cone* model' developed by Ferdows and De Meyer (1990). This approach considers that every factory should focus on a single objective at any single moment in time, as there is a logical sequence that should be followed, in order to achieve substantial improvements in all of them. More specifically, the initial

1
2
3 emphasis should be placed on obtaining quality and, once a suitable quality level has been attained, then work
4 should be begun on improving delivery. But at the same time, work should continue on quality. When a suitable
5 standard has been reached for delivery, work should begin on flexibility, while continuing with the two objectives
6 already reached. Finally, having reaching the desired level of flexibility, the focus should turn to cost efficiency.
7
8 The model determines that the falling sand broadens at the base while rising in height. In fact, the broadening of
9 the base is related to continuous improvement, because it is a question of improving the objectives reached
10 while trying to achieve the next one. Since the objectives have an accumulative nature and are based on those
11 that have already been achieved, there is no incompatibility preventing them from being achieved. If
12 manufacturing objectives are achieved in this sequential way, they can provide the firm with a powerful and
13 sustainable competitive advantage because they are based on consistent management practices that are
14 consistent over time and cannot, therefore, be replicated easily or fast by competitors.
15
16

17
18 This approach is based on an original idea by Nakane (1986), although the sequence varies: quality,
19 dependability, cost efficiency and flexibility. However, quality management specialists introduced the idea that
20 quality should receive priority and, until a suitable level has been reached in quality, no steps should be taken to
21 achieve the other objectives. The competitive progression theory (Roth and Giffi, 1995; Roth, 1996) gives a
22 theoretical explanation as well as additional empirical evidence for the *sand cone* model. This theory states that
23 combined, sustainable manufacturing capabilities accumulate in a forward sequential progression –from quality
24 to delivery, flexibility and cost efficiency– by means of an innovation cycle that leads towards strategic agility.
25
26

27
28 Finally, the studies that empirically test the *sand cone* model, in an explicit way, include Noble (1995), White
29 (1996), Kathuria (2000), Corbett and Whybark (2001), Koufteros *et al* (2002), Rosenzweig and Roth (2004),
30 Größler and Grübner (2006), Rosenzweig and Easton (2006), Amoako-Gyampah and Meredith (2007), Wang
31 and Tadisina (2007), Boon-itt and Wong (2008). Flynn and Flynn (2004) find empirical evidence of the link
32 between the accumulation of some manufacturing capabilities and the production department performance, but
33 their results do not support the *sand cone* model. Filippini *et al.* (1998) state that there is evidence of high levels
34 of compatibility among different types of manufacturing performance but is not possible to consider that *trade-off*
35 model has been overcome.
36
37

38
39 In spite of the theoretical arguments and the empirical evidence against the *trade-off* model, some authors
40 consider that it can be applied in certain circumstances. They even maintain that it is possible to combine the two
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 models (*trade-off* and *sand cone*) as they offer complementary approaches. It should be stressed in this
4 connection that manufacturing capabilities depend on the technology used. If the factory operates below the
5 technological frontier of its manufacturing possibilities, it can improve in all the objectives simultaneously. When it
6 reaches the frontier, *trade-offs* occur. But if the frontier moves, there will be further room for simultaneously
7 achieving the objectives (Clark, 1996; Schmenner and Swink, 1998). As stated by Skinner (1992), changing
8 technology changes the *trade-offs* and the links between the design of a manufacturing system and the
9 objectives. In other words, a factory that uses a manufacturing system that is within the technological standard
10 for the industry (at the technological frontier) cannot expect to improve two or more objectives simultaneously
11 (Ferdows and De Meyer, 1990). Lapré and Scudder (2004) provide empirical evidence from the airline industry
12 that the *sand cone* model is applicable when firms are operating further away from their asset frontiers, although
13 *trade-offs* occur when operating close to asset frontiers.

27 **2.3. An extended sand-cone model: Research hypotheses**

28
29 Based on a review of the literature, the aim of this study is to test, in a sample of manufacturers located in Spain,
30 whether or not there are *trade-offs* amongst the manufacturing capabilities, that is, whether firms are able to
31 achieve excellent results in several manufacturing objectives simultaneously and also whether the different
32 manufacturing capabilities strengthen each other. Considering the literature on the environmental protection
33 objective and the interactions between it and the four traditional manufacturing objectives (Del Brío *et al.*, 2005),
34 in our research the sequence is completed by including the environmental protection as the fifth manufacturing
35 objective.

36
37 De Burgos and Céspedes (2001) explain the need for including the environmental protection as an objective for
38 the production department, and state that there are direct links between the environmental protection strategy
39 and the production department. The authors point to the existence of synergies between environmental
40 protection and improvement programs and activities and operating methods and practices. They also indicate
41 that environmental protection management programs should be implemented taking into account and supporting
42 manufacturing strategy. This means that the objectives for the operations area should be expanded to include
43 environmental protection considerations. Angell (1999) proposes that inclusion of the environment protection as
44 a manufacturing objective could be the first step towards achieving a sustainable environmental protection

1
2
3 strategy. Reduction of the environmental impact should be considered, at least partially, a matter for the
4 production department (Angell and Klassen, 1999).
5
6

7
8 Previous studies have analysed the impact of the results of environmental protection management on the
9 production department (see, for example, Gupta and Sharma, 1996; Klassen and Angell, 1998), identifying
10 possible synergies between environmental protection improvement and manufacturing objectives. De Burgos
11 and Céspedes (2001) state that it would be interesting to analyse the link between this environmental protection
12 objective and the other manufacturing objectives as well as the existence of a possible logical sequence for
13 achieving lasting improvements in the manufacturing objectives in the long term.
14
15

16
17 Regarding this sequence and on the basis of previous studies (Noble, 1995; Ferdows and De Meyer, 1990;
18 Rosenzweig and Roth, 2004), it can be assumed that improvements in quality serve as a basis for the
19 improvement of the other objectives. Specifically, quality is hypothesized to have a significant positive relation
20 with delivery. Delivery refers to a firm's ability to provide fast and dependable deliveries; therefore, it comprises
21 two elements: a) speed, and b) reliability. Schroeder *et al.* (1996) argue that conformance quality will drive higher
22 levels of on-time deliveries and fast deliveries. When a factory improves its quality, its processes become more
23 stable and reliable and less time and cost are needed for re-processing tasks (Rosenzweig and Roth, 2004).
24 When quality improves, the number of items requiring re-work becomes smaller. This allows materials to move
25 more swiftly and consistently through a process and cycle times to become more predictable. Reductions in the
26 lead time, set-up time and delivery time depend on the reliability of the processes and on a consistently high
27 product quality level (Sakakibara *et al.*, 1997). Consistent with this, Wacker (1987, 1996) mathematically
28 demonstrates that a reduction in defect rates can have a positive effect on throughput time and delivery
29 reliability, a compatible relationship that has also been reported by other authors (Schroeder *et al.*, 1996; Vickery
30 *et al.*, 1997; Safizadeh *et al.*, 2000). Taking this into account, it could be argued that a production process with
31 high levels of internal quality may facilitate delivery commitments (quoted and/or forecasted) based on the
32 process output (Sarmiento *et al.*, 2007). In other words, higher levels of quality may lead to enhanced delivery,
33 so the following hypothesis is established:
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56

57 *H₁: Improving quality has a direct, positive effect on delivery.*
58
59
60

1
2
3 Nevertheless, upstream in the sand-cone model, delivery is assumed to positively affect flexibility. Flexibility
4 measures the capability for manufacturing to adapt to changing market needs. This objective involves several
5 facets (De Toni and Tonchia, 1998): a) the possibility of changing manufacturing volume to meet fluctuations in
6 demand without any significant effect on cost efficiency –volume flexibility; b) the skill to modify the
7 characteristics of existing products –product flexibility; and c) the skill to place new products on the market fast –
8 flexibility in innovation. In fact, some studies show that delivery reliability and various dimensions of flexibility
9 (e.g. product mix and volume changes) may be compatible and are positively associated (Vickery *et al.*, 1997).
10 High-speed manufacturing improves flexibility in that less time is needed for responding to different external
11 influences and adjusting to changes in requirements or specifications (Milling *et al.*, 2000). Corbett and Van
12 Wassenhove (1993) assert that if the organization is unable to meet due dates under normal circumstances, it
13 will be unable to react flexibly to unforeseen volume fluctuations in demand. This is consistent with the
14 comments by Wacker (1987) who argues that, as throughput time increases, a firm becomes less productive and
15 less able to respond to changes in output mix and customer demand responsiveness. Therefore, the following
16 hypothesis is established:

17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34 *H₂: Improving delivery has a direct, positive effect on flexibility.*

35 Manufacturing flexibility, by enabling efficient adaptation to change and uncertainty, can support environmental
36 practices (Klassen and Angell, 1998). Improving innovation in both products and processes promotes the
37 incorporation of more flexible, more environment-friendly technology. It also enables the development of make-
38 to-order production systems that can operate with lower inventory levels. Such systems reduce shrinkage and
39 limit the obsolescence of stored products which otherwise would have to be eliminated, reprocessed or recycled,
40 and this reduces environmental impact. Moreover, production systems involving more flexible processes (such
41 as just-in-time) may promote the adoption of more advanced environmental practices which might improve the
42 company's overall environmental situation (Del Brío *et al.*, 2005). This argument is to some extent consistent with
43 studies that have empirically noted synergies amongst some lean manufacturing processes and environmental
44 practices (King and Lenox, 2001; Rothenberg *et al.*, 2001). The following hypothesis is therefore posed:

45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
H₃: Improving flexibility has a direct, positive effect on the environmental protection objective.

1
2
3 Direct synergies can also be observed between environmental protection and cost reduction. For example, the
4 development of an overall pollution prevention strategy (which only requires limited additional investments,
5 compared with add-on equipment for an end-of-pipe strategy) may result in reduced operating costs and
6 efficiency improvements (Wagner, 2005). Additionally, the introduction of technologies that aim to improve firms'
7 environmental protection situation (for example, reducing energy consumption during the production process) or
8 the re-examination of the actual production processes also help to save costs (Porter and van der Linde, 1995a,
9 1995b; Angel and Klassen, 1999). This was exemplified by Dorfman *et al.*, 1992, who reported annual cost
10 savings of \$740,000 at Ciba-Geigy's dyestuff plant in New Jersey as a result of re-examining its wastewater
11 streams and operating processes and replacing some production components. Similarly, Sheridan (1992)
12 reported how 3M implemented a new production technique that allowed it to reduce hazardous wastes by 10
13 tons per year at almost no cost, yielding annual savings of more than \$200,000. Van Wassenhove and Corbett
14 (1991) reported how AT&T saved US\$1.4 million on recycling efforts alone, whereas the Gulf Coast Acid Team,
15 a task force of employees at Dow Chemical, recommended installation of a state-of-the-art recycling system that
16 resulted in an annual saving of US\$20 million.

17
18 Solving environmental problems can also yield benefits in terms of lower costs due to reduced downtime.
19 Parkinson (1990) described how installing higher quality monitoring equipment allowed DuPont to reduce
20 production interruptions and the associated wasteful production start-ups in many chemical production
21 processes, thus reducing waste generation as well as downtime.

22
23 The implementation of environmental initiatives aiming to substitute materials, reuse or recycle production inputs,
24 use less packaging, reduce storage, make work conditions safer, improve monitoring and maintenance, etc.,
25 may lead to higher resource productivity (Porter and van der Linde, 1995b). Basta and Vagi (1988) reported
26 several cases of successful waste reduction projects in the chemical industry that illustrate the positive effects of
27 "green" initiatives on cost savings. With regard to certain ecological products, it is possible to go even further,
28 with firms recovering waste products for re-manufacturing, thus achieving a cost reduction advantage (Ayres *et*
29 *al.*, 1997). As pointed out by Porter and van der Linde (1995b), solving environmental problems by using
30 recyclable products can lead to designs that allow valuable materials to be recovered more easily after disposal
31 of the product; in this case, whoever takes back used products –either the customer or the manufacturer– gains
32 greater value.

1
2
3 Environmental management may also improve firms' process excellence by using environmental management
4 tools which support identification of eco-efficiency potential and successful implementation of eco-efficiency
5 enhancing measures (Wagner and Schaltegger, 2001). In this way, as shown empirically by Carter and Carter
6 (1998), environmental protection improvement, which in turn helps make the firm eco-efficient, leads to reduced
7 costs (Gupta and Sharma, 1996). Or, to state this in more formal terms:
8
9

10
11
12
13
14 *H₄: Environmental protection improvement has a direct, positive effect on cost efficiency.*
15
16

17
18 The hypotheses H₁-H₄ capture the direct effects of improving a given capability on the capability succeeding it in
19 the depicted progression. However, the literature suggests that the development of these capabilities in this
20 successive fashion may lead to indirect and cumulative effects. As previous authors suggest (Nakane, 1986;
21 Ferdows and De Meyer, 1990; Schmenner and Swink, 1988; Swink and Way, 1995; Flynn and Flynn, 2004),
22 quality can be viewed as the foundation for the development of cumulative capabilities. The literature documents
23 many cases and examples that illustrate the positive effect of quality on other manufacturing capabilities. Quality
24 management systems have synergies with flexibility and environmental protection management (Kitazawa and
25 Sarkis, 2000). The quality improvement stabilizes production processes, eliminating reprocessing tasks and
26 saving energy and resources (Rosenzweig and Roth, 2004). A reduction in lead times not only reduces
27 inventories but also shortens internal product transport time, eliminating the need for repeat consignments
28 (because deliveries are reliable), which also saves energy (Koufteros *et al.*, 2002) and reduces costs. Flexibility
29 leads to a reduction in inventories and therefore fewer products are spoilt while fewer resources are used, which
30 contributes to environmental protection and cost savings. Consequently, contrary to the theory that *trade-offs*
31 exist among manufacturing capabilities, cost efficiency in production can be achieved more easily through
32 improvements in other capabilities. Therefore, considering the shared (or common) process variance between
33 enhancement in one capability and improvement in the others, it is possible to assume the existence of positive
34 indirect effects amongst them (Rosenzweig and Roth, 2004). This leads to the following hypotheses:
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53

54
55 *H_{5a}: Improving quality has an indirect, positive effect on flexibility by improving delivery.*
56

57
58 *H_{5b}: Improving quality has an indirect, positive effect on environmental protection by improving delivery and*
59 *flexibility.*
60

1
2
3 H_{5c} : Improving quality has an indirect, positive effect on cost efficiency by improving delivery, flexibility and
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

environmental protection.

H_{6a} : Improving delivery has an indirect, positive effect on environmental protection by improving flexibility.

H_{6b} : Improving delivery has an indirect, positive effect on cost efficiency by improving flexibility and
environmental protection.

H_7 : Improving flexibility has an indirect, positive effect on cost efficiency by improving environmental
protection.

The theoretical reasoning presented above leads us to consider a cumulative manufacturing capabilities model, depicted in **Figure 1**, showing a progression in the achievement of quality, delivery, flexibility, environmental protection and cost efficiency capabilities. By empirically testing this model, we try to answer the following research question: *Do firms accumulate manufacturing capabilities by following the sequence of quality, delivery, flexibility, environmental protection, and cost efficiency, in such a way that the performance achieved in each objective allows improvements in the others?*

INSERT FIGURE 1

3. METHODOLOGY

3.1. Research design and sample characteristics

The information needed for the study was obtained from a survey conducted on 1,234 manufacturers that in 2003 were located in Spain and employed over 100 workers, according to the Amadeus-SABI database. The selection of firms was based on two-digit ISIC codes, including codes 24 and 28 to 36. A detailed description of the research instrument and the sample analysed can be seen at Vázquez-Bustelo *et al.*, 2007.

The questionnaire used was designed on the basis of the existing literature and the conclusions obtained from a previous case study (Vázquez-Bustelo and Avella, 2006). It was revised by four experts in operations management and two experts in survey design. With the aim of checking its validity and improving its design, a pre-test was also done on a small sample of firms drawn from the population.

The information needed for the study relates to the production function in firms, so the questionnaire was addressed to the plant/operations/manufacturing manager or other similar position, and the strategic manufacturing unit was identified as the unit of analysis. Each strategic manufacturing unit corresponds to a firm,

1
2
3 or a division or plant within a firm, with defined business and manufacturing strategies. A total of 283 valid
4 questionnaires were returned corresponding to 274 different firms and representing a valid response rate of
5 22.2%. Using a Student T-test, the last 25% of respondents were compared to earlier ones and no statistically
6 significant differences were found in key variables at the 5% level. Based on the assumption that late
7 respondents are similar to non-respondents (Armstrong and Overton, 1977), non-response bias does not appear
8 to be a major problem in this research.
9

16 **3.2. Measurement of variables**

10 For each of the 22 items of the five manufacturing objectives considered in this research (**Table 1**), managers
11 were asked to indicate on a five-point scale (1 = poor/lower; 3 = average; 5 = excellent/higher), the strength or
12 advantage developed in comparison to its competitors. In this way we measure manufacturing capability in each
13 dimension of the five manufacturing objectives considered in this research.
14

15 Before testing the hypotheses, the metric properties of the scales for the five manufacturing capabilities were
16 evaluated, that is, the unidimensionality, reliability and validity.
17

18 Exploratory factor analysis was carried out using Varimax rotation to determine the dimensions underlying the set
19 of variables in each scale (**Table 2**). The 22 variables were grouped in five factors relating to cost efficiency (4
20 items), flexibility (6 items), quality (5 items), delivery (3 items) and environmental protection (4 items) with factor
21 loadings above 0.5 and a percentage of total accumulated explained variance of over 50%.
22

23 **INSERT TABLE 2**

24 After exploratory factor analysis, confirmatory factor analysis (CFA) was carried out by means of structural
25 equations, using the EQS statistical package, which confirmed the composition of the scales identified in the
26 previous exploratory factor analyses for the manufacturing capabilities –strength developed in each of the
27 manufacturing objectives– (**Table 3**).
28

29 **INSERT TABLE 3**

30 In order to analyse reliability, Cronbach's alpha coefficient and the composite reliability coefficient were
31 calculated (**Table 3**). Cronbach's alpha coefficient in all cases was over 0.7, the criterion usually considered to
32 identify strict internal consistency. In all cases the composite reliability coefficient was over the minimum level of
33 0.6 recommended by Bagozzi and Yi (1988).
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 After studying the unidimensionality and testing for reliability, the content, convergent and discriminant validity
4 were analysed. Content validity indicates that the items considered are suitable for representing the concepts to
5 be analysed. The 18 measures used for the four traditional manufacturing objectives (cost efficiency, quality,
6 flexibility and delivery) are an adaptation of those used in the Global Manufacturing Futures Survey Project-
7 GMFSP (Miller *et al.*, 1992) and are consistent with the measures used in other empirical studies on
8 manufacturing strategy (Roth, 1996; Corbett, 1996; Avella *et al.*, 1998; Gilgeous, 2001, among others). The
9 items used for measuring the environmental protection objective are also based on the extant literature (Porter
10 and van der Linde, 1995a; Shrivastava, 1995a, 1995b; Gupta and Sharma, 1996; Newman and Hanna, 1996;
11 Ayres *et al.*, 1997; Klassen and Angell, 1998; Angell and Klassen, 1999; Kitazawa and Sarkis, 2000). Only those
12 categories in which the manufacturing area is directly responsible are included.

13
14 Since the scales were built on the basis of the previous literature and therefore include items used in scales that
15 had already been validated for measuring similar concepts and assessed by case studies and the questionnaire
16 pre-test, it was considered that each item had the necessary content validity.

17
18 Convergent validity measures the degree to which the different scales used to measure a latent factor are
19 correlated. It can be assessed from the measurement model by determining whether each indicator's estimated
20 pattern coefficient on its posited underlying construct factor is significant (Anderson and Gerbing, 1988).
21 Following Anderson and Gerbing's method, the lambda coefficients that measure the relation between the
22 observed and the latent variable were analysed observing that all the standardized factor loadings were
23 statistically significant at a 95% confidence level ($t > 1.96$, weak condition) and exceeded 0.5 (strong condition)
24 **(Table 3)**.

25
26 The discriminant validity measures the degree to which the specified latent factors differ even though they are
27 correlated. It was tested by calculating and examining the confidence interval of the paired correlations among
28 the latent variables (i.e., \pm two standard errors; Marcoulides, 1998). As shown in **Table 3**, the discriminant
29 validity of the scales can be confirmed because none of these confidence intervals contains the value 1.0 at 95%
30 confidence (Bagozzi and Phillips, 1982; Anderson and Gerbing, 1988; Torkzadeh *et al.*, 2003). However, the
31 idea of the existence of synergies or reinforcements amongst the various objectives suggests that the factors
32 that measure the objectives should have a certain degree of correlation. Table 4 shows the correlation matrix
33 amongst the various objectives. The results presented indicate that the correlations between the objectives are

1
2
3 moderate, in no case above 0.7. This allows us to conclude that the factors measure different concepts and can
4
5 be treated as different statistical objects.
6

7 8 INSERT TABLE 4

9 10 4. RESULTS

11 In order to analyse the data and test the hypotheses, a structural equation model was used. This methodology
12
13 allowed us to carry out statistical validation of the model proposed by means of simultaneous analysis of the
14
15 whole system of variables involved and their links, determining the degree to which the analysis is consistent
16
17 with the data. Use of this technique allows the researcher to simultaneously compare many equations and
18
19 explore both the direct and indirect effects of the variables, offering a more precise measure of the overall effect
20
21 of one variable on another.
22
23

24 If the chi-square test is considered in isolation, the model does not reach the recommended criterion for good fit.
25
26 However, the possibility of using the chi-square test is limited and has been questioned in the literature (Bagozzi
27
28 and Yi, 1988) because it does not take into account the complexity of the model tested.
29
30

31 To solve this limitation, its value should be divided by the degrees of freedom. This quotient should be 3 or
32
33 below, a criterion which is achieved in this model ($S-B \chi^2 / df = 1.95 < 3$). The values reached by other robust
34
35 indices (BBNNFI = 0.921 > 0.9) (CFI = 0.930 > 0.9) (IFI = 0.931 > 0.9) (RMSEA = 0.058 < 0.08) also support the
36
37 model's goodness of fit and allow us to confirm the plausibility of the links proposed between the variables
38
39 involved.
40
41

42 The estimated value and the sign of the links (direct and indirect effects) between the five manufacturing
43
44 objectives are shown in **Table 5**.
45
46

47 48 INSERT TABLE 5

49 The results of testing the model support the hypothesis that improved manufacturing objectives can be achieved
50
51 progressively and without incompatibility or direct *trade-offs* between them. The results of the multi-variant
52
53 analysis offer evidence that backs up the theory of the sequential or *sand cone* model (**Figure 2**).
54
55

56 57 INSERT FIGURE 2

58 The specific link between quality and delivery (H_1) is backed by the empirical evidence that points to the
59
60 existence of a direct, positive, significant link at 99% confidence between the former and the latter (t value =
9.040). Similar results can be observed for the other hypotheses that indicate direct effects amongst the

1
2
3 remaining manufacturing objectives. They show that greater delivery speed and dependability has a positive
4 effect on flexibility ($p < 0.01$), thus supporting hypothesis H₂. The data also support hypothesis H₃, noting a direct,
5 positive, significant effect (t value = 5.543) of flexibility on environmental protection. Finally, the t value of the
6 non-standard coefficient 0.348 illustrates the existence of a direct, positive, and significant effect ($p < 0.01$) of
7 environmental protection on cost efficiency, which supports hypothesis H₄.
8
9

10 **Table 5** shows that a higher level in quality has an indirect effect on cost efficiency ($p < 0.01$) through an
11 improvement in the delivery, flexibility and environmental protection. These results support hypotheses H_{5a}, H_{5b},
12 H_{5c}. With regard to H_{6a}, H_{6b}, the results indicate that improved delivery have an indirect, positive effect on cost
13 efficiency (t value = 3.219), through increased flexibility and environmental protection improvement ($p < 0.01$).
14 Finally, the results support the last of the hypotheses (H₇), indicating that flexibility has an indirect effect on cost
15 efficiency ($p < 0.01$) as a result of greater environmental protection.
16
17

18 5. DISCUSSION

19 Our results point out that not only can *trade-offs* be avoided altogether, but in fact one capability would enhance
20 another. Specifically, our findings provide empirical evidence supporting an extended *sand cone* model which
21 includes the environmental protection objective alongside the four traditional manufacturing capabilities –quality,
22 delivery, flexibility and cost efficiency. Our data show the system of simultaneous dependence that exists in the
23 process of improving these five manufacturing capabilities and suggest that it is possible to reject the existence
24 of *trade-offs* or incompatibilities among them, thus providing empirical support for the cumulative aspects of the
25 manufacturing capabilities analysed.
26
27

28 Nowadays, compared to their competitors, excellent manufacturers seem to achieve better quality, to be more
29 dependable, more flexible, and more environment conscious and, in spite of all that, to achieve cost efficiency.
30 Maybe the pursuit of intelligent production-competition strategies that try to overcome the traditional duality of
31 cost leadership or differentiation (Bullinger and Schweizer, 2006), the generalized implementation of advanced
32 manufacturing technologies (AMT) and other world-class practices and organisational improvements (New,
33 1992) have helped such firms to concurrently develop multiple capabilities avoiding *trade-offs* between them.
34 These findings are in line with the arguments of previous authors (Ferdows and De Meyer, 1990; Swink and
35 Way, 1995; Schmenner and Swink, 1998) and also support the idea that addressing capabilities in a particular
36 sequence enables improvements to be made in other capabilities.
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 The relationship among capabilities suggested in our model and our results would appear to have some
4 theoretical and practical implications.
5

6
7 From a theoretical point of view, this paper highlights the need to adopt an integrated perspective for
8 environmental operations management, and justify the need to include environmental protection as a dimension
9 of operations performance in manufacturing strategy studies. The paper contributes to the field of operations
10 management by exploring the direct and indirect connections between capabilities for a large sample of
11 manufacturers. Our findings on the relationship among manufacturing capabilities and their sequence may offer
12 a way of better understanding manufacturing competence, which determine manufacturing's contribution to the
13 success of a firm.
14
15

16 Since our findings suggest that improvement in certain manufacturing capabilities can amplify certain other
17 capabilities, managers can conclude that developing multiple capabilities simultaneously is possible and
18 desirable. Our model also suggest to practitioners that an efficient development path to overall improvement in
19 manufacturing capabilities exist, and it can be used as a guide when constructing manufacturing strategies and
20 designing programmes to improve performance of manufacturing systems. The sequence, strength and direction
21 of the tested relationships between the five manufacturing capabilities considered in our paper may play a major
22 role conducting firm's resource allocation and leading the emphasis placed by managers on the improvement of
23 different capabilities. Particularly, our findings suggest that improvements on the quality dimension have a strong
24 positive impact on improvements on delivery capabilities and, by supporting delivery, capabilities on a higher
25 level (e.g. flexibility, environmental protection and cost efficiency) jointly benefit from achievements on quality.
26 Thus, as the other capabilities benefit from quality, management attention should first be directed toward
27 achieving and then expanding it. Quality management (control, assurance and improvement) may serve a
28 primary building block for gaining cumulative capabilities. This assertion is consistent with previous studies that
29 observe quality management to form a strong foundation for cumulative capabilities (Flynn and Flynn, 2004).
30 Quality-related principles, initiatives, practices and action programmes (e.g. Process Statistical Control, ISO
31 9000, *kaizen*, six sigma, TQM, quality circles, QFD, etc.) may function as drivers to enhance supportive links
32 between the manufacturing capabilities. One explanation may be related to the fact that the work processes
33 associated with quality management may also have interdependent properties, or "process commonalities" that
34 overlap with other management practices related with the enhancement of different capabilities. Thus, the
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 improvement of one capability maybe acts synergistically to automatically modify other capabilities with which it
4 shares common processes (Rosenzweig and Roth, 2004). This argument can be a plausible explanation of the
5 indirect links and cumulative effects observed in the structure of capabilities presented in our paper. After
6 achieving the quality-related objective and while quality efforts are further expanded, attention should be directed
7 toward the improvement of delivery capabilities. Delivery (dependability and speed) is closely related to
8 organisational integration, supply chain management and lean manufacturing (Flynn and Flynn, 2004). In this
9 second layer, management should focus their strategic initiatives on developing effective supplier relationships
10 and incorporating external supply chain management practices internally. Relationship-building initiatives such
11 as just-in-time (JIT) manufacturing, supplier certification and customer integration, for example, can clearly
12 change delivery reliability and speed, and synergistically amplify other capabilities on a higher level, such as
13 flexibility, environmental protection or cost efficiency. Once significant performance has been achieved in quality
14 and delivery and while pursuing these objectives further, resources may be directed toward improving
15 manufacturing flexibility by proper product-process integration and close coordination between manufacturing
16 activities and suppliers and/or customers. In this third layer, the activities initiated during the previous stages of
17 the improvement progression facilitate the possibility of changing manufacturing volume to meet fluctuations in
18 demand without incurring high penalties, and enhance skills in both modifying the characteristics of existing
19 products or processes, and placing new products on the market fast. A close coordination with suppliers that
20 provide slack capacity, absorb demand fluctuations or exchange technological expertise, and the information
21 sharing and degree of process integration with customers may be key for directly acquiring flexibility capability
22 and affecting the remaining capabilities indirectly. While efforts continue toward achieving and expanding quality,
23 delivery and flexibility, attention can then be directed toward improving environmental protection. Since
24 environmental protection as strategic capability is supported by other capabilities and reinforce each other (De
25 Burgos and Céspedes, 2001), managers should develop policies and implement environmental management
26 programmes with similarities and synergies with the strategic operations initiatives already in place. Proactive
27 environmental strategies (e.g. Design for environment (DfE), total quality environment management (TQEM), life
28 cycle assessment (LCA), total recycling, source reduction/pollution-prevention (SR/P2), or zero emissions) would
29 have a positive affect on cost cutting via waste reduction and other factors that reflect an eco-efficient approach.
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

6. CONCLUSIONS

The purpose of this study was to determine which model for improving manufacturing objectives prevails in firms. Are there incompatibilities (*trade-offs*) among the different manufacturing capabilities? Or, on the contrary, are firms able to obtain high scores in several manufacturing objectives simultaneously and do the various manufacturing capabilities strengthen each other?

The study began with a review of the literature and the design of a model structuring the links among the five key manufacturing objectives –quality, delivery, flexibility, environmental protection and cost efficiency. After drawing up a precise definition of these objectives, the measurement scales for the constructs were validated, and the set of links proposed was tested using structural equation modelling. The results of the multi-variant analysis showed that the predominant model in these firms is one of multiple, non-incompatible capabilities with cumulative effects according to the following sequence: quality, delivery, flexibility, environmental protection and cost efficiency. It was noted that the five manufacturing objectives considered in the research not only are not incompatible with each other but that improvements in quality have a positive effect on delivery, flexibility, environmental protection and cost efficiency as do each of the objectives on the others, so they strengthen each other and produce cumulative effects.

Thus, this study makes a dual contribution. On the one hand, it offers additional empirical evidence on the existence of cumulative links amongst the four classic manufacturing objectives: quality, delivery, flexibility and cost efficiency, as suggested both by the *sand cone* model (Ferdows and De Meyer, 1990) and the competitive progression theory (Roth, 1996; Rosenzweig and Roth, 2004). On the other, it adopts an integrated perspective for environmental operations management, validating an extended *sand cone* model which considers environmental protection management alongside the four traditional objectives.

In spite of its contribution, the study has certain limitations that represent challenges for further research. On the theoretical side, the absence of *trade-offs* among the capabilities may be explained by the fact that the manufacturing units studied are positioned further from their performance, technological or assets frontier (Schmenner and Swink, 1998; Rosenzweig and Roth, 2004). However, our research does not consider the viewpoint of performance frontiers, an aspect that should be addressed in future research. Since we did not include the consideration of contingencies as Swink and Way (1995) suggest, and did not compare the influence of different structures of capabilities on business performance (measured, for example by market share, ROI or

1
2
3 other indices) one has to be careful to interpret the specific structure of operations-based capabilities presented
4 in this paper as the “one best way” to firm’s competitiveness and success. This paper also uses a
5 conceptualization of environmental protection mainly focused on internal issues, although an internal perspective
6 to environmental protection may be insufficient to actually improve a firm’s environmental objective.
7
8

9
10 On the methodological side, obtaining information by means of a survey may generate doubts about the validity
11 of the information provided by respondents. This problem may be solved by obtaining information from more than
12 one source for each unit of analysis (that is to say, from more than one respondent), but this research did not
13 consider this possibility, as it would have had important negative effects on the response rate. For this reason,
14 single respondent bias can be considered a limitation for this empirical research. This study also uses
15 managerial perceptions to measure the manufacturing capabilities. Perceptual measures of performance have
16 often been used to measure operational performance because of the difficulty associated with obtaining
17 comparable, objective measures for large samples. Objective measures are not normally available at the
18 manufacturing level, or firms are reluctant to facilitate such information. Although this approach is a common
19 procedure in management research, objective measures might improve the validity of our results. The lack of
20 objective measures to complement the subjective/perceptual measures used can be considered a limitation.
21 Also, this research adopts a cross-cutting approach when it considers the manufacturing strengths achieved by
22 the firms analysed at a specific moment in time, which limits the discussion of causality. Although plausible
23 theoretical inter-relationships among capabilities have been drawn from the literature, and prior research (Noble,
24 1995; Rosenzweig and Roth, 2004) has stated that the path dependency of manufacturing capabilities generally
25 holds over time, our inferences on a time sequence with respect to capability development should be interpreted
26 with caution. Future research should carry out a longitudinal analysis of the link between the various
27 manufacturing objectives, including environmental protection, in order to offer stronger empirical support for the
28 time process-model of capabilities development. It should also adopt a contingent approach (Noble, 1995;
29 Schaltegger and Synnestvedt, 2002; Flynn and Flynn, 2004; Sousa and Voss, 2008), evaluating the robustness
30 of the results when considering context factors such as firm size and age, industry, type of production process,
31 customer behaviour, business environment or national context and culture.
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

ACKNOWLEDGEMENTS

The authors would like to thank the Editor and the anonymous referees for their helpful comments and suggestions. The authors also would like to thank Spanish Ministerio de Ciencia y Tecnologia (SEJ2006-04753/ECON) in its financial support. A preliminary version of this paper was published as Working Paper N^o. 371/2008 in Colección de Documentos de Trabajo de la Fundación de las Cajas de Ahorros (FUNCAS).

REFERENCES

- Amoako-Gyampah, K. and Meredith, J. R., 2007. Examining cumulative capabilities in a developing economy. *International Journal of Operations & Production Management*, 27 (9), 928-950.
- Anderson J. C. and Gerbing D. W., 1988. Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin*, 103 (3), 411-423.
- Angell, L. C., 1999. Environmental and Operations Management face the future. *Decision Line*. May, 9-11.
- Angell, L. C. and Klassen, R. D., 1999. Integrating environmental issues into the mainstream. An agenda for research in operations management. *Journal of Operations and Production Management*, 11 (3), 63-76.
- Aragón-Correa, J. A., Hurtado-Torres, N., Sharma, S. and García-Morales, V. J., 2008. Environmental strategy and performance in small firms: A resource-based perspective. *Journal of Environmental Management*, 86 (1), 88-103.
- Armstrong, J. S. and Overton, T. S., 1977. Estimating non response bias in mail surveys. *Journal of Marketing Research*, 14, 396-402.
- Avella, L., Fernández, E. and Vázquez, C. J., 1998. Taxonomy of the manufacturing strategies of large Spanish industrial companies. *International Journal of Production Research*, 36 (11), 3113-3134.
- Ayres, R., Ferrer, G. and van Leynseele, T., 1997. Ecoefficiency, asset recovery and remanufacturing. *European Management Journal*, 15 (5), 557-574.
- Bagozzi, R. and Phillips, L., 1982. Representing and testing organizational theories: A holistic construal. *Administrative Science Quarterly*, 27, 459-489.
- Bagozzi, R. P. and Yi, Y., 1988. On the evaluation of structural equation models. *Journal of the Academy of Marketing Science*, 16 (1), 74-97.

- 1
2
3 Banks, R. Y. and Wheelwright, S. C., 1979. Operations versus strategy -Trading tomorrow for today. *Harvard*
4
5 *Business Review*. May-June, 112-120.
6
7 Basta, N. and Vagi, D., 1988. A casebook of successful waste reduction projects. *Chemical Engineering*, August
8
9 15, (95), 11, 37.
10
11 Boon-itt, S. and Wong, C. Y., 2008. The relationships between manufacturing capabilities: An empirical analysis
12
13 in Thai automotive industry. In Amasaka, K., Matsui, Y., Matsuo, H. & Morita, M. (Eds.), *Manufacturing*
14
15 *Fundamentals: Necessity and Sufficiency*, Proceedings of the Third World Conference on Production and
16
17 Operations Management POM, August 5-8, 2008, Tokyo, Japan, 101-115.
18
19 Bullinger, H.-J., Schweizer, W., 2006. Intelligent production-competition strategies for production enterprises.
20
21 *International Journal of Production Research*, 44 (18-19), 3575-3584.
22
23
24 Carter, C. R. and Carter, J. R., 1998. Interorganizational determinants of environmental purchasing. Initial
25
26 evidence from the consumer products industries. *Decision Sciences*, 29 (3), 659-684.
27
28 Clark, K. B., 1996. Competing through manufacturing and the new manufacturing paradigm. Is manufacturing
29
30 strategy passé?. *Production and Operations Management*, 5 (1), spring, 42-57.
31
32
33 Corbett, L. M., 1996. A comparative study of the operations strategies of globally- and domestically-oriented New
34
35 Zealand manufacturing firms. *International Journal of Production Research*, 34 (10), 2677-2689.
36
37 Corbett, L. M. and Whybark, D. C., 2001. *Searching for the sandcone in the GMRG data*, Working Paper, Victoria
38
39 University, New Zealand and University of North Carolina, Chapel Hill, USA.
40
41 Dangayach, G. S., Deshmukh, S. G., 2001. Practice of manufacturing strategy: evidence from select Indian
42
43 automobile companies. *International Journal of Production Research*, 39 (11), 2353-2393.
44
45
46 De Burgos, J. and Céspedes, J. J., 2001. Environmental performance as an operations objective. *International*
47
48 *Journal of Operations & Production Management*, 21 (12), 1553-1572.
49
50 De Toni, A. and Tonchia, S., 1998. Manufacturing Flexibility: A Literature Review. *International Journal of*
51
52 *Production Research*, 36 (6), 1587-1617.
53
54 Del Brío, J., Fernández, E. and Junquera, B., 2005. Competitive effects from eco-manufacturing strategy.
55
56 Influencing factors. In: Sharma, S. and Aragón-Correa, J.A. (Eds.), *Corporate Environmental Strategy and*
57
58 *Competitive Advantage*. Cheltenham, UK: Edward Elgar.
59
60

- 1
2
3 Dorfman, M. H., Warren, R. M. and Miller, C. G., 1992. *Environmental Dividends: Cutting More Chemical*
4 *Wastes*. New York: INFORM.
- 5
6
7 Fawcett, S. E., Calantone, R. and Smith, S. R., 1997. Delivery capability and firm performance in international
8 operations. *International Journal of Production Economics*, 51, 191–204.
- 9
10
11 Ferdows, K. and De Meyer, A., 1990. Lasting improvements in manufacturing performance. In search of a new
12 theory. *Journal of Operations Management*, 9 (2), 168-184.
- 13
14
15 Filippini, R., Forza, C., Vinelli, A. 1998. Trade-off and compatibility between performance: definitions and
16 empirical evidence, *International Journal of Production Research*, 36 (12), 3379-3406.
- 17
18
19 Flynn, B. B. and Flynn, E. J., 2004. An exploratory study of the nature of cumulative capabilities. *Journal of*
20 *Operations Management*, 22, 439-457.
- 21
22
23
24
25 Garvin, D. A., 1983. Quality on the line. *Harvard Business Review*. September-October, 65-75.
- 26
27 Gilgeous, V., 2001. The strategic role of manufacturing, *International Journal of Production Research*, 39 (6),
28 1257-1287.
- 29
30
31 Größler, A. and Grüßner, A., 2006. An empirical model of the relationships between manufacturing capabilities.
32 *International Journal of Operations & Production Management*, 26 (5), 458-485.
- 33
34
35 Gupta, M. C. and Sharma, K., 1996. Environmental operations management. An opportunity for improvement.
36 *Production and Inventory Management Journal*, 37(3), 40-46.
- 37
38
39 Handfield, R. B., Walton, S. V., Seeger, L. K. and Melnyk, S. A., 1997. Green value chain practices in the
40 furniture industry. *Journal of Operations Management*, 15 (4), 293-315.
- 41
42
43 Harbour, J. L., 1996. *Cycle Time Reduction – Designing and streamlining Work for High Performance*. Portland,
44 Oregon: Productivity Press.
- 45
46
47 Hayes, R. H. and Pisano, G., 1994. Beyond the world class. The new manufacturing strategy. *Harvard Business*
48 *Review*, January-February, 77-86.
- 49
50
51 Hayes, R. H. and Schmenner, R. W., 1978. How should you organize manufacturing?. *Harvard Business*
52 *Review*, January-February, 105-119.
- 53
54
55 Hayes, R. H. and Wheelwright, S. C., 1984. *Restoring Our Competitive Edge*. New York: John Wiley.
- 56
57
58 Hofer, C. W. and Schendel, D., 1978. *Strategy Formulation. Analytical Concepts*. St. Paul, Minnesota: West
59 Publishing Co.
60

- 1
2
3 Huges, E. C. and Anderson, A. D., 1988. *The Spirit of Manufacturing Excellence*. Homewood, IL: Dow-Jones-
4 Irwin.
5
6
7 Inman, R. A., 2002. Implications of environmental management for operations management. *Production Planning*
8 *and Control*, 13 (1), 47-55.
9
10
11 Kathuria, R., 2000. Competitive priorities and managerial performance. A taxonomy of small manufacturers.
12 *Journal of Operations Management*, 18, 627-641.
13
14
15 King, A. A. and Lenox, M. J., 2001. Lean and green? An empirical examination of the relationship between lean
16 production and environmental performance. *Production and Operations Management*, 10, 244-256.
17
18
19 Kitazawa, S. and Sarkis, J., 2000. The relationship between ISO 14001 and continuous source reduction
20 programs. *International Journal of Operations & Production Management*, 20 (2), 225-248.
21
22
23 Klassen, R. D. and Angell, L. C., 1998. An international comparison of environmental management in operations.
24 The impact of manufacturing flexibility in the US and Germany. *Journal of Operations Management*, 6 (2-3),
25 177-194.
26
27
28 Kleindorfer, P. R., Singhal, K. and Van Wassenhove, L. N., 2005. Sustainable Operations Management.
29 *Production and Operations Management*, 14 (4), 482-492.
30
31
32 Koufteros, X. A., Vonderembse, M. A. and Doll, W. J., 2002. Examining the competitive capabilities of
33 manufacturing firms. *Structural Equation Modeling*, 9 (2), 256-282.
34
35
36 Lapré, M. A. and Scudder, G. D., 2004. Performance improvement paths in the U.S. Airline Industry. Linking
37 trade-offs to asset frontiers. *Production and Operations Management*, 13 (2), 123-134.
38
39
40 Marcoulides, G. A., 1998. *Modern methods for business research*. Mahwah, NJ: Lawrence Erlbaum Associates,
41 Inc.
42
43
44 Miller, J. G., De Meyer, A. and Nakane, J., 1992. *Global Benchmarking in Manufacturing*. Homewood, ILL:
45 Business One Irwin.
46
47
48 Milling, P. M., Schwellbach, U. and Thun, J-H., 2000. Time as a success factor for operations management –an
49 empirical analysis based on the World Class Manufacturing –Project. In: Van Dierdonck, R. and Vereecke, A.
50 (Eds.), *Operations Management. Crossing Borders and Boundaries*, Ghent, pp. 431-438.
51
52
53 Nakane, J., 1986. Manufacturing Futures Survey in Japan. A comparative survey 1983-1986, *Systems Science*
54 *Institute*, Waseda University, May, Tokyo.
55
56
57
58
59
60

- 1
2
3 New, C., 1992. World-class manufacturing versus strategic trade-offs. *International Journal of Operations &*
4
5 *Production Management*, 12 (6), pp. 19-31.
6
7
8 Newman, W. R. and Hanna, M. D., 1996. An empirical exploration of the relationship between manufacturing
9
10 strategy and environmental management. Two complementary models. *International Journal of Operations &*
11
12 *Production Management*, 16 (4), 69-87.
13
14 Noble, M. A., 1995. Manufacturing strategy. Testing the cumulative model in a multiple country context. *Decision*
15
16 *Sciences*, 26 (5), 693-721.
17
18
19 Parkinson, G., 1990. Reducing wastes can be cost-effective. *Chemical Engineering*, 97 (7), 30-33.
20
21 Porter, M. E. and van der Linde, C., 1995a. Green and competitive. Ending the stalemate. *Harvard Business*
22
23 *Review*, September-October, 120-137.
24
25 Porter, M. E. and van der Linde, C., 1995b. Toward a new conception of the environment-competitiveness
26
27 relationship. *Journal of Economic Perspectives*, 9 (4), 97-118.
28
29 Rosenzweig, E. D. and Easton, G. S., 2006. Is the tradeoffs model dead?. Evidence using modified meta-
30
31 analysis methods, *Working Paper*, The Goizueta Business School, Atlanta.
32
33 Rosenzweig, E. D. and Roth, A. V., 2004. Towards a theory of competitive progression. Evidence from high-tech
34
35 manufacturing. *Production and Operations Management*, 13 (4), 354-368.
36
37 Roth, A. V., 1996. Neo-Operations strategy. Linking capabilities-based competition to technology. In: Gaynor, G.
38
39 H. (Ed.), *Handbook of Technology Management*. New York: McGraw-Hill, 38.1-38.44.
40
41 Roth, A. V. and Giffi, C. A., 1995. Winning in global markets. Neo-operations strategies in U.S. and Japanese
42
43 manufacturing. *Operations Management Review*, 10 (4), 1-35.
44
45
46 Rothenberg, S., Frits, K. P. and Maxwell, J., 2001. Lean green and the quest for superior environmental
47
48 performance. *Production and Operations Management*, 10, 228-243.
49
50 Safizadeh, M., Ritzman, L. and Mallick, D., 2000. Alternative paradigms in manufacturing strategy. *Production*
51
52 *and Operations Management*, 9 (2), 111-127.
53
54
55 Sakakibara, S., Flynn, B. B., Schroeder, R. G. and Morris, W. T., 1997. The impact of just in time manufacturing
56
57 and its infrastructure on manufacturing performance. *Management Science*, 43 (9), 1246-1257.
58
59
60

- 1
2
3 Sarmiento, R., Byrne, M., Contreras, L. R. and Rich, N., 2007. Delivery reliability, manufacturing capabilities and
4 new models of manufacturing efficiency. *Journal of Manufacturing Technology and Management*, 18 (4), 367-
5 386.
6
7
8
9
10 Schaltegger, S. and Synnestvedt, T., 2002. The link between 'green' and economic success: environmental
11 management as the crucial trigger between environmental and economic performance. *Journal of*
12 *Environmental Management*, 65, 339-346.
13
14
15
16 Schmenner, R. W. and Swink, M. L., 1998. On theory in Operations Management. *Journal of Operations*
17 *Management*, 17 (1), 97-113.
18
19
20 Schroeder, R. G., Flynn, E. J., Flynn, B. B. and Hollingworth, D., 1996. Manufacturing performance trade-offs: an
21 empirical investigation, paper presented at 3rd International Conference of the European Operations
22 Management Association, London.
23
24
25
26
27 Sheridan, J. H., 1992. Attacking wastes and saving money...Some of the time. *Industry Week*, February 17, 43-
28 46.
29
30
31 Shrivastava, P., 1995a. Environmental technologies and competitive advantage. *Strategic Management Journal*,
32 16 (3), 183-200.
33
34
35 Shrivastava, P., 1995b. The role of corporations in achieving ecological sustainability. *Academy of Management*
36 *Review*, 20 (4), 936-990.
37
38
39
40 Skinner, W., 1969. Manufacturing -Missing link in corporate strategy. *Harvard Business Review*, May-June, 136-
41 145.
42
43
44 Skinner, W., 1974. The focused factory. *Harvard Business Review*, May-June, 113-121.
45
46
47 Skinner, W., 1992. Missing the links in manufacturing strategy. In: Voss, C. A. (Ed.), *Manufacturing Strategy.*
48 *Process and Content.* London: Chapman and Hall.
49
50
51 Sousa, R. and Voss, C. A., 2008. Contingency research in operations management practices. *Journal of*
52 *Operations Management*, 26 (6), 697-713.
53
54
55 Swink, M. and Way, M. H., 1995. Manufacturing strategy: propositions, current research, renewed directions.
56 *International Journal of Operations and Production Management*, 15, (7), 4-26.
57
58
59
60

- 1
2
3 Van Wassenhove, L. N. and Corbett, C., 1991. How green is your manufacturing strategy. INSEAD R&D,
4
5 Working Paper No. 91/50/TM/SM.
6
7 Vázquez-Bustelo, D. and Avella, L., 2006. Agile manufacturing. Industrial case studies in Spain. *Technovation*,
8
9 26, 1147-1161.
10
11 Vázquez-Bustelo, D., Avella, L. and Fernández, E., 2007. Agility drivers, enablers and outcomes. Empirical test
12
13 of an integrated agile manufacturing model. *International Journal of Operations & Production Management*,
14
15 27 (12), 1303-1332.
16
17
18 Vickery, S. K., Dröge, C. and Markland, R. E., 1997. Dimensions of manufacturing strength in the furniture
19
20 industry. *Journal of Operations Management*, 15 (4), 317-330.
21
22
23 Wacker, J. G., 1987. The complementary nature of manufacturing goals by their relationship to throughput time:
24
25 a theory of internal variability of production systems. *Journal of Operations Management*, 7 (1/2), 91-106.
26
27
28 Wacker, J. G., 1996. A theoretical model of manufacturing lead-times and their relationship to a manufacturing
29
30 goal hierarchy. *Decision Sciences*, 27 (3), 483-517.
31
32
33 Wagner, M., 2005. How to reconcile environmental and economic performance to improve corporate
34
35 sustainability: Corporate environmental strategies in the European paper industry. *Journal of Environmental*
36
37 *Management*, 76, 105-118.
38
39 Wagner, M. and Schaltegger, S., 2001. Umweltmanagement in Deutschen Unternehmen. Der aktuelle Satand der
40
41 Praxis (Environmental Management in Practice). In: Baumast, A. and Dyllick (eds.), Umweltmanagement-
42
43 Barometer 2001, Gallen: IWÖ-Discussion Peper (93), 5-15.
44
45 Wang, D. and Tadisina, S., 2007, When the sand cone model meets SMEs, POMS 18 th Annual Conference
46
47 proceedings, Dallas, Texas, 4-7 May.
48
49 Welford, R., 1992. Linking quality and the environment: A strategy for the implementation of environmental
50
51 management systems. *Business Strategy and the Environment*, 1 (1), 25-34.
52
53
54 White, G. P., 1996. A meta-analysis model of manufacturing capabilities. *Journal of Operations*
55
56 *Management*, 14 (4), pp. 315-331.
57
58
59
60

Figure 1. Manufacturing capabilities cumulative model

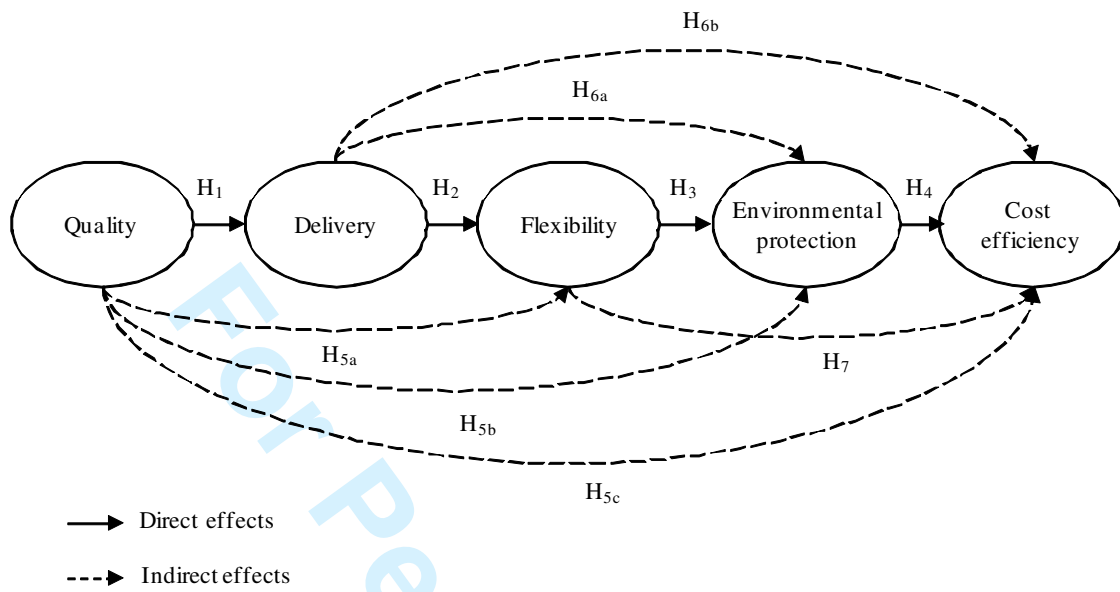


Figure 2. Estimated cumulative model

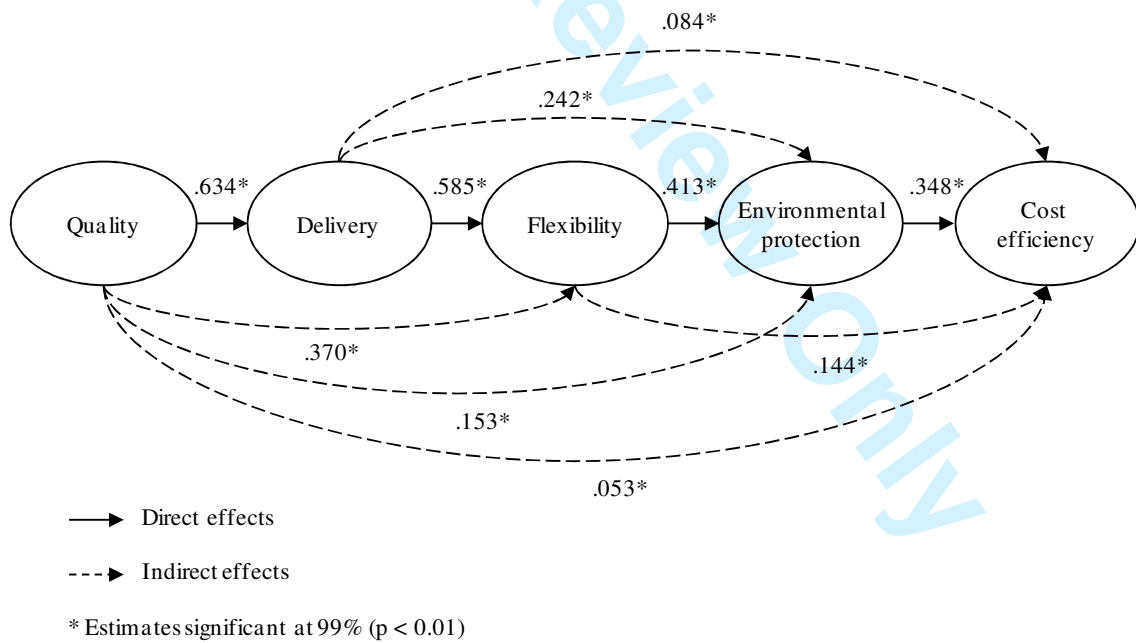


Table 1. Competitive manufacturing objectives

Factor	Variables	Code	Description of item
Competitive manufacturing objectives	Cost efficiency	Cost1	Reduce manufacturing cost
		Cost2	Increase labour productivity
		Cost3	Increase equipment or capacity utilization
		Cost4	Reduce inventory level
	Flexibility	Flex1	Make rapid design changes
		Flex2	Introduce new products quickly
		Flex3	Make rapid volume changes
		Flex4	Make rapid product mix changes
		Flex5	Offer a large degree of product variety (broad product line)
		Flex6	Adjust product mix
	Quality	Quali1	Improve conformance to design specifications
		Quali2	Offer consistent, reliable quality
		Quali3	Provide high-performance products
		Quali4	Offer durable, reliable products
		Quali5	Manufacture with consistently low-defect rates (reduce defect rates)
	Delivery	Deliver1	Provide fast deliveries
		Deliver2	Meet delivery promises or commitments
		Deliver3	Reduce manufacturing lead time
	Environmental protection	Enviro1	Make environmental-friendly products
		Enviro2	Use environment-friendly production processes
Enviro3		Provide the firm with a positive environmental image	
Enviro4		Prevent environmental incidents	

Table 2. Exploratory factor analysis

Items	Manufacturing objectives				
	Factors				
	1	2	3	4	5
Cost efficiency1	.083	.128	.077	.784	.151
Cost efficiency2	-.028	.077	.111	.758	.162
Cost efficiency3	.162	.136	.119	.643	.087
Cost efficiency4	.216	.093	.149	.583	.133
Flex1	.114	.684	.211	.276	-.017
Flex2	.117	.590	.340	.214	-.072
Flex3	.098	.536	.212	.325	.229
Flex4	.109	.777	.125	.127	.140
Flex5	.059	.708	.129	-.087	.155
Flex6	.086	.701	-.157	.030	.235
Quali1	.162	.038	.703	.294	.323
Quali2	.139	.083	.656	.333	.316
Quali3	.136	.283	.749	.030	.058
Quali4	.159	.136	.819	.028	.033
Quali5	.131	.110	.557	.471	.181
Deliver1	.160	.212	.116	.148	.807
Deliver2	.144	.120	.153	.213	.793
Deliver3	.140	.190	.223	.235	.702
Enviro1	.874	.118	.164	.084	.131
Enviro2	.906	.105	.124	.067	.115
Enviro3	.879	.150	.132	.180	.110
Enviro4	.881	.101	.154	.160	.128
Explained variance (66.049%)	15.660%	13.737%	13.420%	12.759%	10.472%
Extraction method: main components Varimax Rotation with Kaiser					
Kaiser–Meyer–Olkin Measure of Sampling Adequacy 0.875					
Bartlett 's test of Sphericity Approx. Chi-Square: 3304.53 d.f. 231 (Sig. 0.000)					

Table 3. Confirmatory factor analysis

Factor (Latent Variable)	Item	Mean	Std. Dev.	Standard lambda parameters (t-value)	Reliability		Discriminant validity	
					Cronbach's alpha	Composite reliability index	Factor	Correlation coefficient (confidence interval)
Cost efficiency (F1)	Cost1	3.471	0.624	0.775 (14.187)	0.738	0.750		
	Cost2			0.715 (11.731)				
	Cost3			0.56 (8.536)				
	Cost4			0.556 (8.963)				
Flexibility (F2)	Flex1	3.485	0.672	0.639 (9.702)	0.805	0.805	F1-F2	(0.321 – 0.609)
	Flex2			0.567 (8.708)			F1-F3	(0.508 – 0.704)
	Flex3			0.652 (10.385)			F1-F4	(0.433 – 0.681)
	Flex4			0.787 (13.935)			F1-F5	(0.217 – 0.477)
	Flex5			0.604 (9.272)			F2-F3	(0.360 – 0.600)
	Flex6			0.574 (10.012)			F2-F4	(0.421 – 0.641)
Quality (F3)	Quali1	4.011	0.629	0.851 (19.041)	0.844	0.836	F2-F5	(0.242 – 0.498)
	Quali2			0.844 (20.249)			F3-F4	(0.504 – 0.720)
	Quali3			0.553 (9.516)			F3-F5	(0.319 – 0.555)
	Quali4			0.581 (10.342)			F4-F5	(0.294 – 0.542)
	Quali5			0.698 (14.190)				
Delivery (F4)	Deliver1	3.999	0.738	0.79 (14.420)	0.819	0.820		
	Deliver2			0.78 (12.973)				
	Deliver3			0.759 (13.575)				
Environmental protection (F5)	Enviro1	3.846	0.801	0.867 (19.574)	0.941	0.941		
	Enviro2			0.899 (20.291)				
	Enviro3			0.905 (22.396)				
	Enviro4			0.906 (19.543)				
Measures of the model's goodness of fit (Robust Method)								
S-B $\chi^2 = 303.58$ (d.f. 197) $p = 0.000$ BBNNFI = 0.955 CFI = 0.962 IFI = 0.962 RMSEA = 0.044								

Table 4. Correlation matrix between objectives

	Delivery	Flexibility	Environmental protection	Cost efficiency
Quality	0.612	0.480	0.437	0.606
Delivery	1.00	0.531	0.418	0.557
Flexibility		1.00	0.370	0.465
Environmental protection			1.00	0.347
Cost efficiency				1.00
Note: All the correlations are significant at 99% ($p < 0.01$)				
Measures of the model's goodness of fit (Robust Method)				
S-B $\chi^2 = 303.58$ (d.f. 197) $p = 0.000$ BBNNFI = 0.955 CFI = 0.962 IFI = 0.962 RMSEA = 0.044				

Table 5. Breakdown of effects: direct and indirect effects. Standard coefficients and goodness of fit (robust statistics)

EFFECT OF...	ON...								
	Delivery		Flexibility		Environmental protection		Cost efficiency		
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect	
Quality	0.634 (9.040) R ² = 0.402	-----	-----	0.370 (4.489)	-----	0.153 (4.157)	-----	0.053 (3.057)	
Delivery	-----	-----	0.585 (5.925) R ² = 0.342	-----	-----	0.242 (5.000)	-----	0.084 (3.219)	
Flexibility	-----	-----	-----	-----	0.413 (5.543) R ² = 0.171	-----	-----	0.144 (3.448)	
Environmental protection	-----	-----	-----	-----	-----	-----	0.348 (4.661) R ² = 0.121	-----	
t values between brackets All estimates are significant at 99% (p<0.01)									
Measures of the model's goodness of fit (Robust Method)									
S-B $\chi^2=397.33$ (d.f. 203) $p = 0.000$			BBNFI = 0.921		CFI = 0.930		IFI = 0.931		RMSEA = 0.058