Catalogs of Split-Plot Type Designs for Physical Prototype Testing

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INTRODUCTION

- During the design of an experiment one of the challenges is to balance limited resources and system constraints to obtain useful information.
- It is common that prototypes are composed of several parts, with some parts more difficult to assemble than others.
- Usually, there is only one piece available of each part type and a large number of different setups.
- Designs with randomization restrictions are attractive approaches.
- Considering this scenario, a new and additional criterion to construct split-plot type designs is presented.
- Illustration with the assembly of a Baja car prototype.

OBJECTIVE

- Proposal of a new criterion – designs with a small number of setups of the more difficult parts, which are especially useful for screening purposes in physical prototype testing.
- Development of the theoretical properties of the designs - minimum number of setups (MS) at each stratum.
- Construction of catalogs of selected 32-run split-split-plot and split-split-split-plot designs.

APPLICATION - BAJA COMPETITION EXPERIMENT

- The Society of Automotive Engineers (SAE) promotes the development of college students through car competitions all over the world.
- The objective of the experiment is to maximize the performance of the vehicle on two tests carried out on a paved street with an asphalt layer.
- The first one, called acceleration test, evaluates the time that the vehicle takes to cover a distance of 30 meters starting from a complete stop.
- The second one, called velocity test, measures the final velocity reached by the Baja at the 100 meters mark

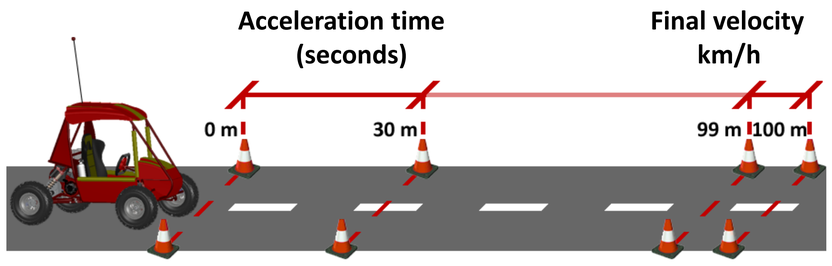

Figure 1. Illustration of the acceleration and velocity tests.

Table 1. Factors according to their degrees of difficulty in changing their levels – split[3]-plot experiment

+ difficult	→		+ easy
Group 1	Group 2	Group 3	Group 4
Ceasefire plate setting (A)	Driven pulley cam angle (B) Driven pulley material (C) Driven pulley spring (D) Driven pulley spring pressure (E)	Driver pulley cap (F) Driver pulley masses (G) Driver pulley springs (H)	Tire pressure (J)

CATALOGS OF MINIMUM SETUP DESIGNS

- Split[3]-plot and split[4]-plot designs.
- Seven to eleven factors.
- Sixteen to thirty two runs.

Table 2: Minimum number of setups 32-run two-level split[2]-plot designs

#	# factors			# of generators			# setups				Design			WLP									
											stratum 1	stratum 2	stratum 3	3	4	5	6	7	8	9	10	R	C1	C2
7	3	1	3	1	0	1	4	8	32	3			29	1	0	1	1					3	4	18
7	3	2	2	1	1	0	4	8	32	3		5		2	1	0	0	0				3	2	11
7	3	3	1	1	1	0	4	16	32	3		13		1	1	1	0	0				3	4	12
7	4	2	1	1	1	0	8	16	32	7		11		0	3	0	0	0				4	7	6
7	5	1	1	2	0	0	8	16	32	3	5			2	1	0	0	0				3	2	11
8	3	1	4	1	0	2	4	8	32	3			13 22	1	2	3	1	0				3	5	13
8	3	2	3	1	1	1	4	8	32	3		5	30	2	1	2	2	0				3	3	18
8	3	3	2	1	2	0	4	8	32	3		5 6		4	3	0	0	0				3	2	13
8	3	4	1	1	2	0	4	16	32	3		5 14		2	3	2	0	0				3	3	9
8	4	3	1	1	2	0	8	16	32	7		11 13		0	7	0	0	0				4	8	7
8	5	2	1	2	1	0	8	16	32	3	5	14		2	3	2	0	0				3	3	9
8	6	1	1	3	0	0	8	16	32	3	5 6			4	3	0	0	0				3	2	13
9	3	1	5	1	0	3	4	8	32	3			13 21 26	1	5	6	2	1				3	6	9
9	3	2	4	1	1	2	4	8	32	3		5	14 25	2	4	6	2	0	1			3	4	11
9	3	3	3	1	2	1	4	8	32	3		5 6	31	4	3	3	4	0	0	1		3	3	21
9	3	4	2	1	3	0	4	8	32	3		5 6 7		7	7	0	0	1				3	2	15
9	3	5	1	1	3	0	4	16	32	3		5 9 14		3	7	4	0	1				3	2	9
9	4	4	1	1	3	0	8	16	32	7		11 13 14		0	14	0	0	0	1			4	9	8
9	5	3	1	2	2	0	8	16	32	3	5	9 14		3	7	4	0	1				3	2	9
9	6	2	1	3	1	0	8	16	32	3	5 6	15		4	6	4	0	0	1			3	3	8
9	7	1	1	4	0	0	8	16	32	3	5 6 7			7	7	0	0	1				3	2	15
10	3	1	6	1	0	4	4	8	32	3			13 21 25 30	1	10	11	4	3	1	1		3	7	8
10	3	2	5	1	1	3	4	8	32	3		5	14 22 25	2	8	12	4	2	3			3	5	4
10	3	3	4	1	2	2	4	8	32	3		5 6	9 30	5	6	7	8	3	1	1		3	2	13
10	3	4	3	1	3	1	4	8	32	3		5 6 7	25	7	8	3	4	5	3	1		3	3	18
10	3	5	2	1	3	1	4	16	32	3		5 9 14	31	3	8	11	4	1	3	1		3	3	12
10	3	6	1	1	4	0	4	16	32	3		5 9 14 15		4	14	8	0	4	1			3	1	9
10	4	4	2	1	3	1	8	16	32	7		11 13 14	19	0	18	0	8	0	5			4	10	0
10	4	5	1	1	4	0	8	16	32	3		5 9 14 15		4	14	8	0	4	1			3	1	9
10	5	3	2	2	2	1	8	16	32	3	5	9 14	31	3	8	11	4	1	3	1		3	3	12
10	5	4	1	2	3	0	8	16	32	3	5	9 14 15		4	14	8	0	4	1			3	1	9
10	6	2	2	3	1	1	8	16	32	3	5 6	9	30	5	6	7	8	3	1	1		3	2	13
10	6	3	1	3	2	0	8	16	32	3	5 6	9 14		6	10	8	4	2	1			3	1	9
10	7	1	2	4	0	1	8	16	32	3	5 6 7		25	7	8	3	4	5	3	1		3	3	18
10	7	2	1	4	1	0	8	16	32	3	5 6 7	9		8	10	4	4	4	1			3	0	0

CONCLUSION

- In physical prototype testing experiments with factors which levels have different degrees of difficulty to change, split-plot type designs represent a cost-effective method for the generation of information to guide the decision-making process.
- The basic steps for planning these experiments are (1) identification of the factors and the corresponding degrees of difficulty to change their levels, (2) grouping of the factors with similar degrees of difficulty, and (3) choice of a convenient design.
- The analysis should be conducted on a stratum-by-stratum basis.

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