abutments) for all three cases. Instead, though, of increasing and decreasing the span by a certain number of feet, it may be necessary to reduce and augment the number of spans by unity. After the costs of the arches and piers or abutments are found and properly combined, the cost of these two portions of the construction per lineal foot of span for each of the three layouts can be computed and compared. The one which gives a minimum will indicate approximately the best span-length to adopt.

In some cases it will prove to be economic to make the middle span of the bridge a certain length and reduce gradually the lengths of the spans at each side. If the configuration of the crossing will permit of a symmetrical layout on this basis, the effect will prove to be pleasing to the eye and generally economic of first cost, especially if a constant ratio of rise to span be maintained; because, as far as cost of substructure is concerned, the overturning moments from live load on a single span only and from inequality of dead load thrusts are kept low, owing to the fact that the lighter thrusts in the smaller span act with a greater lever arm than do the heavier thrusts of the longer span, on account of higher location of the points of springing. In adopting this expedient, though, care has to be exercised to prevent the principles of esthetics from being violated.

Comparing rolled I-beam and plate-girder deck spans for modern heavy live loads, the weights of metal are about equal for spans of 15 ft.; but the former are cheaper per pound than the latter by about 0.4 ct., consequently the costs per lineal foot erected are equal to a span of about 20 ft.

Comparing deck plate-girders and through, riveted truss-spans, for which there is usually a difference of about ½ ct. per pound erected in favor of the former, the weights of metal per lineal foot are the same for spans of 115 ft., which is about the extreme limit of length for plate-girder spans shipped in one piece; hence it may be concluded that for all practicable lengths, deck plate-girder spans are more economic than through, riveted truss-spans. Besides, the use of such deck spans effects a great economy in the substructure by reducing the length of each pier from 6 to 10 ft., the longer the span, of course, the less the reduction. It generally reduces also the heights of the piers.

Comparing half-through, plate-girder spans and through, riveted truss-spans, for which there is a difference of about 0.2 ct. per pound erected in favor of the former, the weights of metal per lineal foot are the same for spans of 70 ft., but the costs per foot are about equal for spans of 75 ft. However, as plate-girder spans are in many respects more satisfactory than short, through, riveted spans, the dividing point is generally placed at about 100 ft.

Comparing Pratt and Petit truss-spans, for which there is no difference worth mentioning in the pound prices of the metal, the weights per foot (and therefore the costs) are alike for single-track spans of 300 ft., and for double-track spans of 350 ft.; but both constructive and esthetic reasons necessitate limiting the lengths of Pratt trusses to about 325 ft.

The economics of column spacing for bents when cantilever brackets are employed is an interesting little problem, but the final determination must be in accordance with good judgment as well as economy; for if the spacing be too small, rigidity is likely to be sacrificed. Upon certain assumptions of approximate correctness, the mathematical solution of this problem is a possibility; but the equations involved would be so complicated that it is much better for any particular case to assume two or three spacings, compute the total weight of metal in the bent for each, and find the one which will give approximately the least weight of metal. If the columns are placed at the quarter points of the beam, the dead load bending moment at the middle will be approximately zero; and if the effect of stress reversion is ignored, the direct and reverse bending moments for the central portion of the beam will be equal, and this arrangement would be about the most economical possible. But if the reversion is considered, the sectional area of the middle portion of the beam must be greater than that of the outside portions, hence for economy its length should be somewhat less than one-half of the total, and the columns would then be spaced somewhat closer than when they are located at the quarter points. The fact that the brackets are usually lighter near the outer ends than at the inner ones would, for economy, tend to draw the columns together; but on the other hand this would increase the weight of the splices and connecting details. The proper column spacing to adopt will depend upon the length of the columns; for it is easily conceivable that the structure could be so high and so narrow that the quarter-point spacing would be too close for proper resistance to wind pressure. Again, in such a case the wind load might be so great as to necessitate an increase in column section above that required to care for the live and dead load stresses only; and thus the effect of wind pressure would enter the economic study. It will be found in most cases that it is inadvisable to space the columns much less than one-half of the total length of the beam.

The economic functions of swing spans are somewhat difficult to formulate. The minimum perpendicular distance between central planes of trusses for first-class construction should be the same as for simple-truss spans—*viz.*, one-twentieth of the span length. It is evident, of course, that the narrower the bridge the less it will weigh and cost. The truss depth at ends of through swing bridges are generally determined by the clearance requirements; but in long spans it is sometimes advisable, for the sake of vertical stiffness and to avoid the raising of span-end from a load on the other arm, to make the said depths still greater. As a rule, this increase is not of an uneconomic nature. For long spans, or those exceeding, say, 400 ft., the truss depth at outer hips should be about 1/14th or 1/15th of the total span length. The truss depth at the inner hips should generally be from 1/9th to 1/10th of the total span length; and when towers are used, their height should generally be from 1/6th to 1/7th of the span. Of course the esthetic features of the design should govern greatly the determination of all these depths; and, fortunately, any moderate change in them does not affect materially their economics.

In swing spans it is evident that, as far as is consistent with safety, the diameter of the drum for economy should be made as small as possible, not only because this effects a saving of metal, but also because it reduces the diameter, and therefore the cost, of the pivot pier. For spans of moderate length and width there is generally a small economy in centre-bearing swing-spans over rim-bearing ones, especially as the former sometimes permit of smaller pivot piers, but the difference is often inconsiderable. There is a limit to the size of centre-bearing swing-spans due to the objectionable feature of concentrating great loads upon small areas and to the necessity in the case of very wide spans for excessively heavy cross-girders. The question of economics between the two styles of swings