Industrial location theory in German thought - Launhardt and Weber

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It is standard practice for commentators on the "Weberian" theory of industrial location to outline its history, explaining who first formulated the location problem, and who first proposed a solution. These two questions call for two answers, or at any rate attempts at answers.

The formulation of the location problem is the more fundamental issue for economists, while its solution is more a matter for engineering and operational research. Kuhn [1967] gave a brief historical account of solutions to the location problem and Wesolowsky [1993] reviewed the key points ironising that, when it was destroyed in 638 A.D., the library of Alexandria must have included among its 700,000 volumes at least three containing versions of the location problem with solutions, one of which would have been incorrect.

The earliest formulation of the location problem is commonly ascribed to Fermat (1601-1665): given three points in a plane, find a fourth point minimising the sum of the distances to them. Torricelli (1608-1647) is also accredited with several solutions. The list of those who turned to geometry to resolve an unweighted median problem could be extended.

The pace has quickened this century. Weber [1909] enriched the location problem by introducing weights. A practical solution suggested by Weiszfeld [1937] was neglected (possibly because of the type of journal it was published in and its iterative method which was laborious without computers) before being rediscovered by Miehle [1958], Kuhn and Kuenne [1962], and Cooper [1963]. The location problem can be generalised to more than three points with weights and, in Cooper's work it was tied back in with the Weberian economic perspective by making the points places of supply and demand. Other algorithms have been proposed (Schärlig [1973], Perreur [1988]). There have been so many generalisations since that any attempt to classify them has become, in the words of Wesolowsky [1993], a "taxonomist's nightmare".

The problem is two-sided: by interpreting location in economic terms, constraints can be added and the problem enriched making it a subject of predilection for operational research. Wesolowsky [1993] summarises these aspects well. His inquiry concentrates more on the mathematics of the problem and its developments than on its origin, which he implicitly ascribes to Weber. Now it happens that Weber's formulation of location theory amounts to the same thing as the location problem which has so intrigued mathematicians. In attempting to ascribe paternity, it seems worthwhile asking whether it was Weber who first formulated the location problem in this way. If it was not him, then what relations can be established between the precursors and Weber, and what is it that makes Weber's contribution an original one?

1 Chronology

The answer to the first question is clear enough. The economic model developed by Weber in 1909 (formalised in Pick's mathematical appendix) is identical to that formulated by W. Launhardt in 1882 (and even in 1872 as will be shown) and for which he gave a geometrical solution for three points with weights. Launhardt's generalisation for more than three points is invalid. As Friedrich commented in his English translation of Weber [1909/1929[R]] and Ponsard [1958] observed, Weber was not familiar with Launhardt's work. He referred to it only in the preface to the 1922 second edition, and in the *Industrielle Standortslehre* [1914]. It seems it was Bortkiewicz [1910] who brought Launhardt to Weber's notice in a critical review of Weber's theory. It was indeed a case of multiple discovery (Pinto [1977]), of which there have been many in economics.

It appears then that Launhardt was unjustly overlooked by most specialists in spatial economics. But why? His life story goes some way to explaining this. Carl Friedrich Wilhelm Launhardt was born in Hanover in 1832 and died in the same city in 1918. He was a civil engineer with the public highways department, and a contemporary of Cheysson and Colson. In 1869 he became professor of engineering science at Hanover Polytechnical Institute of which he was made Director and then Chancellor when the college became the *Technische Hochschule Hanover*. His entire career was spent in Hanover. He moved primarily in engineering circles, becoming interested in economics through transportation problems (as did Dupuis, Colson and others). He published mainly in engineering journals, but produced a masterly book, *Mathematische Begründung der Volkwirtschaftslehre* [1885], dealing with the location problem solely in terms of market areas. In that he was the precursor of Fetter. Launhardt's book was for J. Schumpeter "the earliest text, so far as I know [...] devoted explicitly to mathematical economics" (Schumpeter [1954]). The language barrier may have limited the impact of Launhardt's work, although his "The Theory of the Trace, Part One: The Commercial Trace" [1900] - "Part Two: The Technical Tracing of Railway" [1902][1] are compilations translated into English for which I know of no single original German text. The work seems to have had only a limited readership, perhaps because of its uninspiring title. It reiterated and supplemented work published earlier in other forms (1872 and 1882 papers) or in part of his *Mathematische Begründung* (*e.g.* chapter 2 on the growth of the art of transportation, or chapter 4 on the market area).

One of the earliest surveys of industrial location literature by Krzyzanowski in 1927 makes no mention of Launhardt, although it does include Bortkiewicz. I feel that this series of observations is enough to explain why Launhardt was forgotten, his work unknown to Weber, and the leading role ascribed to Weber whose work, being more complete on some points, was published in an English translation at Chicago University in 1929.

2 Launhardt's contribution

2.1 From highway planning...

Upon his appointment as professor of engineering science in 1869, Launhardt began by publishing works on infrastructure costs, route planning and pricing. This apparently led him to make a closer study of economics and to utilise his expertise in engineering to draft his *Mathematische Begründung* in which he concentrated more on production and distribution and therefore on the characterisation of market areas. His academic background undoubtedly explains why he approached the problems of industrial location and of communication network nodes in the reverse order from that found in Weber's generalisations of the problem. These problems include the search for the optimum location of the nodes (hubs) connecting given points, with given flow capacities, to form the corresponding network of roads, tunnels, pipes or whatever. Judging from publication dates, Launhardt began in his 1872 paper on the tracing of commercial communication links by looking into the technical aspects of route planning. The criterion for road-building is to reduce total transportation costs (interest on capital plus operating and maintenance costs) to the lowest possible levels.

> "The solution depends as much on the terrain as on the transport conditions, so that the conditions of transport should be studied every bit as carefully as the character of the ground" (Launhardt [1872], p. 520).

[1] This work is analysed in Pinto [1977]. I am grateful to J. Paelinck for providing me with a copy.

It is difficult to deal with the simultaneous influence of two variables. Launhardt suggested leaving the state of the terrain aside and "assuming we were dealing with perfectly uniform and horizontal ground" so that the route need only be planned on the basis of transport costs. He then used the fictitious case of Euclidean space (*i.e.* a continuous uniform plane with straight line movements) to analyse the effect of transportation conditions more closely. It is an approach that has often been used since. In this way he obtained the "transport trace" or "commercial trace". The terrain factor could subsequently be introduced and a study made of how it "deviated" the "technical trace" relative to the "commercial trace".

If three points, A, B and C, are to be linked up, before connecting AB, BC and CA directly, one needs to ask whether it would not be better to connect A, B and C to a point P by constructing secondary lines AP, BP, and CP. Before deciding to build such a point of junction, the best location must be sought, *i.e.* the one that will minimise total transportation costs. This foreshadows the identification of hubs in modern transportation networks. If a designates the volume of annual traffic to or from point A, and similarly for b and c, if in addition d is the transportation cost per kilometre and unit carried, U the annual interest on the capital costs, the yearly maintenance costs per kilometre and all the installation costs — regardless of the amount of traffic — and r, s and t are the distances AP, BP and CP respectively, the total annual cost to be minimised is:

$$S = (U + ad)r + (U + bd)s + (U + cd)t \, .$$

Minimising the expression gives, after rewriting:

$$\frac{\sin \gamma}{\sin \beta} = \frac{U + cd}{U + bd} \, .$$

"The sines of the angles of bifurcation must act at the point of junction as the transport costs per kilometre of the straight lines to be joined". He then proposed a construction based on determining one transportation pole constructed from one side of triangle ABC and of the junction circle (see figure 1). Observing that the forces exerted in the direction of the initial three points A, B and C (the intensity of the forces corresponding to the products of the masses to be carried a, b, c by the cost of transport per kilometre) are in equilibrium at the point of junction, he suggested the ideal location of the junction could be determined by a system of threads tied at a common point and pulled in the directions A, B and C by weights corresponding to the cost of traffic per kilometre (Launhardt [1872], p. 524). This is nothing other than

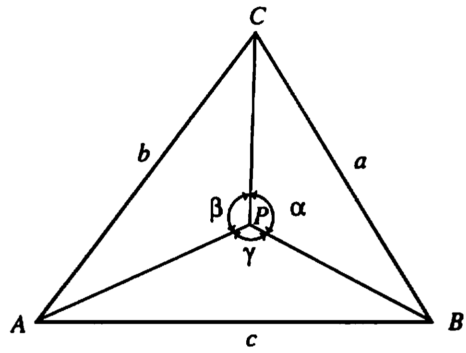

Figure 1: The point of junction (geometrical construction - see appendix)

Varignon's old system which G. Pick suggested should be used to solve a problem with more than three points and which has been employed in practice (Schärlig [1973]). Launhardt also perceived the fundamental role of the relative layout of the points: if one of the angles of the triangle is too obtuse, the point of junction will be brought back to one of the initial points and a single line will connect ABC. There follows an interesting study of the position of the junction of a road linking one point to an existing road depending on the transport costs along these two routes. He then generalised and obtained a set of results containing the law of refraction generally attributed to Palander [1935]. I shall return to this point (2.2, p. 82).

2.2 ... to industrial location

Readers will have recognised the structure of Weber's location problem in the foregoing. It is simply the interpretation of the parameters that changes. Launhardt himself made similar changes in his 1882 paper *Die Bestimmung des Zweckmässigsten Standortes einer Gewerblichen Anlage*, emphasising in his conclusion:

> "the system used here and intended to determine the most profitable place for a firm to set up is an application of the commercial trace theory which I published in 1872" (Launhardt [1882], p. 116).

He established two categories for the determinants of industrial location. The first category of determinants were transportation links, meaning that industrial location is dependent on the places of production of raw materials and of consumption of end-products. The other exceptionally determinant factors such as the difference in land prices, the opportunity costs of energy, the difference in labour costs, etc. cannot be introduced until the optimal location has been determined on the basis of transportation costs. Weber was to proceed in the same way when investigating deviation.

Launhardt started from an example in which a place B supplies the coal needed for processing iron ore from A and the pig iron produced is delivered to C. As in an earlier paper, he calculated the transport costs if the production facility were located at each of the three points. Then, inquiring into what the cost would be if the production facility were located at point P inside the triangle, he wrote the expression for the total transport cost to obtain the minimum by differentiation. He then showed that "optimal location was at the point of equilibrium of transport costs (per kilometre) a, b and c considered as forces" (Launhardt [1882], p. 107). He then suggested either resorting to Varignon's mechanical analogy (already encountered p. 107 of the 1872 paper) or using a geometrical solution that he indicated whereby the location can be found from the transportation pole and the locational circle (junction circle — 1872 — construction shown in appendix). The position of the pole depends exclusively on the weights and on which side of the triangle forms the base of the construction; therefore the location sought will invariably be on the arc of the locational circle lying within the triangle formed by the points of the problem. He further showed that the total transportation cost is equivalent to that which would be incurred by carrying the finished goods between a pole (O) and the vertex of the triangle opposite to it. Having established the construction of the minimum point from one side of the triangle, he studied the displacement of the optimum when the third point (consumption) moved in the plane, while the construction side remained fixed.

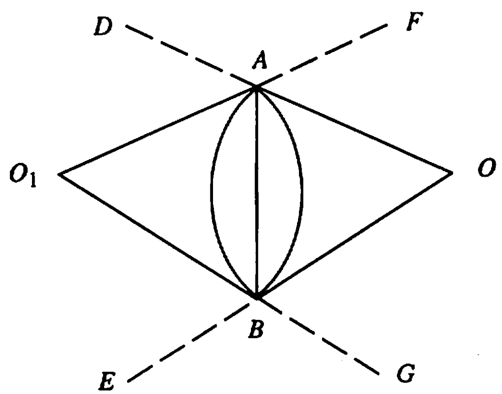

Figure 2: The locus of the optimum

Three cases arise:

1. Point C remains between AD and BE, outside the area of the locational circle, or by symmetry between AF and BG outside the locational circle (also symmetrical to the previous one): the locus

of optimal location is composed of two arcs of a circle subtended by AB and inside the triangle.

2. Point C is located inside angle DAF or angle EBG and angular locations are obtained at A and B respectively.
3. Point C lies between one of the arcs of the circle and side AB. Point C is then the optimum sought. It should be noticed that if point C moves along the straight line OP which joins the pole to the optimum point, beyond the arc of the circle, the optimum remains at P: the optimum location is independent of the consumption centre as long as it remains in this direction.

Two other poles determining the same point P would be obtained from the other two sides of the triangle.

The occupational bias of the highways engineer is discernible in this: he was more attuned to the spatial factors (locations) than to the production factors that influence location. Pick showed that if one of the masses (quantity to be carried) is greater than or equal to the sum of the others (the weight triangle cannot be constructed), the "dominant" point associated with this mass will be the optimum, whatever its position in space. Witzgall [1964] generalised this to the case of n points and displacements represented by a symmetrical weak metric. Nor did Launhardt stress the point that these relative weights (expression of the production function) determine the position of the pole and therefore the position of the semi-straight lines AF, BG, AD and BE of the previous discussion.

Finally, Launhardt illustrated his methodological position defined at the start of the 1882 paper by looking first at the influence of the conditions of transportation and then reintroducing any other factors liable to bring about a deviation from the optimum point.

In his example, the reduction in transportation costs relative to an angular location at the place of extraction A (iron ore or clay) "is tiny" (1%) so that he argued "a location directly at the place of extraction A would be just as satisfactory if administration and surveillance costs could be saved" (Launhardt [1882], p. 109). Nowadays we would speak of vertical agglomeration economies.

He also looked into "transport costs as they occur in reality" (Launhardt [1882], p. 109) relaxing the assumption of "equal accessibility at all places". Coal and ore are carried by rail at a cost made up of a fixed component (interest on the capital costs, plus maintenance and surveillance) and a traffic-dependent component, whereas the pig iron is delivered to the market by road which implies a fixed cost (interest on capital plus maintenance cost) and a variable cost of maintenance and transportation.

He obtained a new optimal location but failed to specify how it was determined. However, it can be deduced from his notation that he resorted to the same pole method using the new per kilometre costs as the weights. It should be noticed that this enhanced cost structure means location is no longer independent of the level of production (maintenance costs are independent of input quantities and depend on output quantities). Weber suggested using a similar procedure to account for differences in freight rates by adding an "ideal weight" to the "real weights" to make the rates uniform (Weber [1909/1971R], p. 44).

For the extension to more than three points, the method proposed by Launhardt using the previous principle of poles is invalid, as indicated by Friedrich in his translation of Weber ([1909/19711971R], note pp. 238-239).

Still with the same concern for relaxing the constraints of the assumptions, Launhardt explained

> "what deviations appear for the most suitable location when this is determined by the use of existing channels of communication (roads, railroads or waterways)" (Launhardt [1882], p. 111).

We discover a demonstration that is closer to, and on some points more thorough than the law of refraction (by analogy with Pascal's law of optics), which is often ascribed to Palander [1935] (Ponsard [1955]).

Just as the pole is the source of the optimum location, Launhardt defined the concept of "access front" for constructing paths.

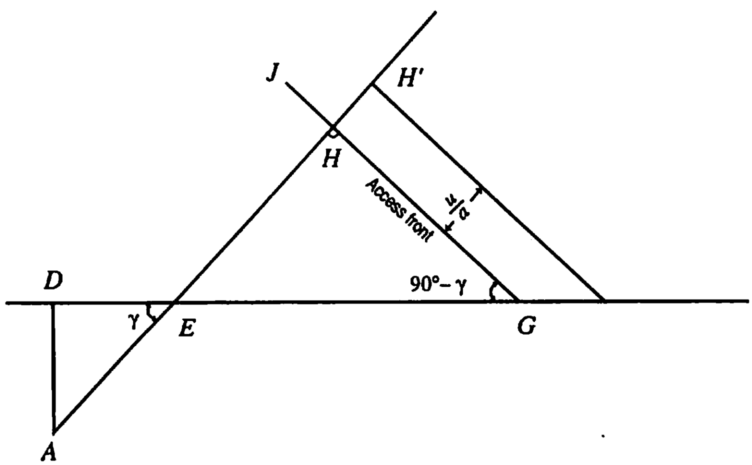

Figure 3: Choice of paths: the access front

To join A to point G, Launhardt showed that the path AEG is followed whenever the costs of transportation per kilometre on AE are

a and e along EG with $e < a$, the angle γ defined by $\cos\gamma = e/a$. The straight line GJ is termed "access front". Point E is then the intersection of the perpendicular to the access front through A. The total transport cost is identical to that which would be obtained by moving from A to H at rate a. If the change of direction at E is accompanied by a change in the means of transportation, the cross-loading costs being U, the access front is translated by length U/a which does not change the position of E but only the total transport cost.

If point B to be reached is on the other side of the existing path (FG, fig. 4) on which the price is lower, the path will be defined in a similar way.

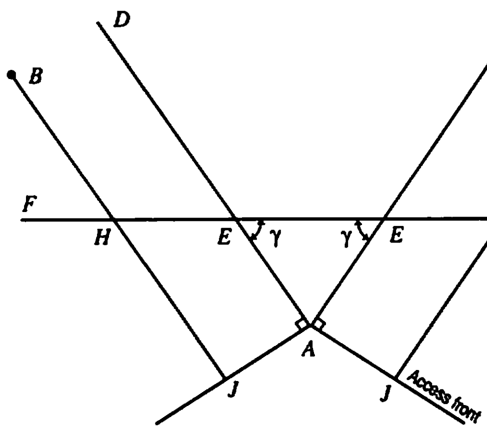

Figure 4
Choice of paths: if the point to be reached is on the other side of the existing path

Thus when B lies inside angles CEG or DEF the path will be $AEHB$. If it is located inside angle ADC, the path will be direct. If a double loading/unloading at E and H is necessary, Launhardt showed that the boundary EC is no longer a straight line but a branch of a parabola.

Launhardt used this result in his location problem to analyse the deviation of the minimum point if an existing road entails a saving on investment.

Let FC be an existing road through the place of consumption C. If a road is constructed from P_1 to C or from P to E, the cost is higher than that incurred on the existing road FC. The rate ratio is rate of $FC/$ rate of PE, which is therefore the sine of the junction angle (γ). An access front is drawn at C forming an angle of $90° - \gamma$ the perpendicular from pole O to the access front indicates the point of junction E and the

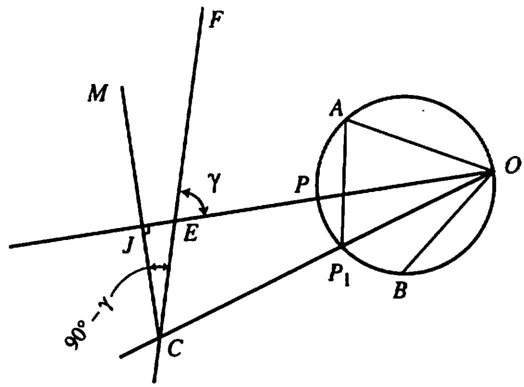

Figure 5: Influence of an existing road

optimum point P which supersedes the former point P_1. If the existing road runs between A and B, the materials are carried to this road and point P is the closest point of junction to C.

2.3 The impact of demand

In the foregoing, Launhardt emphasised the production aspect and the influence of transportation on the costs of production and delivery to a given market. Nothing was said about the market apart from the general study of displacement of the optimum following that of a given point which may, in the case at hand, be the market.

Weber, for his part, provided a fuller explanation. He thought one had to advance gradually in understanding the causes and locations of population agglomeration. Economic theory distinguishes three spheres: production, distribution and consumption which are not completely independent. He wished to consider the places of consumption but his theory by no means explained the location of the commercial centres. He emphasised in his second assumption that the location and size of the places of consumption would be assumed given.

> "We shall thus ignore the fact that each locational distribution of industry, merely by distributing the labour forces, distributes consumption of industrial products and of all other products" (Weber [1909/1971[R], p. 38).

No allusion is made to the effect of transportation cost on the price of goods and consequently of its impact in determining market potential.

Unlike Weber, Launhardt went on to develop a theory of market areas. In this he was something of a pioneer as it was not until Schilling [1924] and Fetter [1924] that the study of market areas was taken up again and the properties that he had highlighted back in 1885 were rediscovered, in a less complete manner. Launhardt himself was unaware of the works of his compatriot Karl H. Rau who in 1841 was the first to speak of market boundary. Schneider [1924] was the first to attribute paternity of this type of work to Launhardt. The history of these rediscoveries is well presented by Robine [1992].

However, Launhardt's analysis of market areas was conducted totally independently of his own works on location to which no reference was made. Isard [1951] regretted that he had not connected these two aspects of his analysis. Ponsard [1958] emphasised that the failure of the attempted synthesis by Englander [1926] meant waiting for contributions from Palander [1935] and Lösch [1944]. Launhardt developed his theory in Part 3 of *Mathematische Begründung* about "the transport of goods". He first defined and calculated the area of supply of a good given that the price of the good increased with the cost of transportation as one moved away from the producer firm. In view of the demands at different points, he determined the radius of the total area of the circular market. He then supposed there were two competitors supplying an identical good at two different places. He showed that, depending on the assumptions used for the prices at the firm and the transport costs, the market boundary would be a Cartesian oval, a circle ($P_A = P_B$, not centred at B), a hyperbola (equal transport costs from A and B) or even the mediator of the segment. He also studied the case whereby two sellers supply different but substitutable products at the same site. The separate areas then become a disc and the surrounding ring, respectively. Finally, he examined the impact of the reduction in transport costs on market organisation and production: the extension of market areas generated specialised manufacturing centres in specific branches inside which were developed what are now known as agglomeration economies: better division of labour, specialisation of firms, creation in the vicinity of specific manufacturing industries and auxiliary industries such that the entire economic character of the area derives from the dominant branch.

3 Should Weber be forgotten?

In view of the foregoing, it is very tempting to speak of Launhardt's or Fermat's location problem. This would be appropriate if we confined ourselves to what is currently presented as Weber's work. However, is such a presentation not an oversimplification?

3.1 Methodology

Weber's primary contribution was perhaps in the method employed, even if, in that regard, he was "the true heir of Thünen" (Blaug [1979]). Weber was one of the very first to apply the hypothetico-deductive method to spatial analysis and he explained his position at length whereas Launhardt did not address the question in his 1882 article. The latter simply defended the use of mathematics in his *Mathematische Begründung* ([1885/1985[R]], Preface, p. 15) without dwelling on the justification of his method.

Weber's scientific environment was marked primarily by the historicist movement, which sought to decry the search for "natural laws" as a crude mistake and viewed historical laws alone as expressions of national custom and character. In Germany, the mainstream often subscribed to an ethical view of political economy, opposing it to individualism and rejecting the separation between science and morality. It also embraced an organicist outlook (Gide [1926]).

The Germans were very much aware of spatial questions, whether addressed theoretically—Thünen, Rau, Launhardt, etc. (Blaug [1979], Ponsard [1958], Robine, [1992])— or more empirically through the historicist current of Roscher and Schaeffle whose works Weber [1909] cited in his introduction and to whom he did not want "to do injustice". The latter school was reinforced from the 1870s with the works of von Schmoller and his disciples. A critical presentation of Weber's methodology was made by Gregory [1981] and discussed and supplemented most perceptively by Genau de Lamarlière [1992]. Both rightly emphasise the ambiguity of Weber's position. He was won over by the positive approach of science but unable to break away entirely from the historicist current. Like his brother Max Weber, he had a grounding in sociology he was never to relinquish and their discussions, like the exchanges with Sombart, marked his work. He published little in economics, unlike Launhardt who opted firmly for an approach that led to his remarkable *Mathematische Begründung*.

This ambiguity marked the plan of the work he wanted to develop. He explained his position clearly in the introduction to his work (and in the preface omitted from the English edition). He sought to understand the

> "enormous displacements of economic forces, migrations of capital and human labour [. . .] We observe that certain regions rapidly grow poor in human beings and capital, while others become saturated. We see in metropolitan centres great masses conglomerate, seemingly without end" (Weber [1909/1971[R]], p. 2).

The study of industrial locations was not an end in itself but was expected to provide insight into how they influence economic forces and affect the distribution of population in industrial regions and large cities.

He proposed to investigate this in two parts: the first contained the pure theory of industrial location "*i.e.* independent of any particular kind of economic system" (Weber [1909/1971R], p. 10) "[since] we have a theory of location of agricultural production by Thünen" (*Ibid.*, p. 5).

The second part set out a realistic theory based on analysis of locations in Germany since 1860 and on available data for other capitalist countries. The aim was not to construct a theoretical model and collect data to test the relevance of its predictions, but rather to establish another explanatory schema derived from this theoretical model by different additions or modifications as

> "the kind of industrial location we have today is not entirely explained by the *pure* rules of location and therefore is not purely *economic*" (Weber [1909/1971R], p. 12).

Location is influenced by certain fundamental aspects of modern capitalism. This

> "*realistic* theory will enable us to arrive at certain fairly general conclusions which explain at least a part of the dynamics of the large modern geographical revolution" (Weber [1909/1971R], p. 13).

His 1909 book contained only part one, part two being found in a more dispersed form in the *Grundriss der Sozialökonomik* (Weber [1914]) and in various contributions by his fellow workers.

Weber proceeded by "isolation" and simplification. First he was only concerned with industrial locations, agriculture being dealt with by Thünen. His primary concern was a general theory (economic, sociological, cultural...) of population movement. His approach was objective, based on observable and measurable relations,

> "by making use of the method of isolating analysis, we may ascertain, if not all, at least some, causal relationships, and prepare for a perfect causal understanding, and even for measurement" (Weber [1909/1971R], pp. 9–10).

He clearly proceeded by the deductive method as attested in chapter 2 dedicated entirely to examining "simplifying assumptions". These are the assumptions that link the problem to that dealt with by Launhardt. In fact, the current presentation of Weber's works can be resumed in this chapter of assumptions and Pick's mathematical appendix.

In fact, Weber's theory is more complete. He reviewed the different location factors (chapter 1) retaining only their substance. For the pure theory, he conserved only the general factors, the special factors concerning individual cases only.

A factor is

> "an advantage which is gained when an economic activity takes place at a particular point or at several such points rather than elsewhere" (Weber [1909/1971R], p. 18).

An advantage is "a cost saving". Factors may also be classified between those leading to the location of industry in one point or region and those leading firms to agglomerate or disperse, regardless of their location. A third useful distinction for his pure theory distinguishes natural and technical factors and social and cultural factors to be integrated in the realist theory.

Thus only the factors accounting for the regional distribution of firms are retained. The influence of agglomerative phenomena is then introduced. This influence is not related to a specific place, even if it leads to precise location relative to the main factor (transportation).

There remains therefore only the influence of raw material costs and of energy costs, differential costs of labour and transportation costs. However, the raw material sources being given, their minimum cost will be influenced by transportation alone, hence the attempt to minimise transportation costs. Because demand is given independently of price, proximity to the market can only be conceived if the costs of transportation are incurred by the firm. Transportation is therefore the synthetic component. Weber explained that the linear form of cost he used might actually include other components by using fictive weights.

Space, for Weber, therefore was a set of different places separated by a distance whose influence had to be reduced.

It is easy, or even simplistic nowadays, to deal with this distance. On this ground, it is often asserted that the model has become less relevant with the decrease in transport costs. The same authors develop proximity economies. In the real world, the structure of transport costs is more complex and they are increasingly separated from geographical locations, and therefore the graphical representation and the geometrical model are outdated.

3.2 Deviations for labour or agglomeration savings

The point of minimum transport cost is not necessarily the location chosen. There may be a deviation to take advantage of a lower labour cost or agglomeration economy. Weber analysed both types of deviation.

3.2.1 Labour orientation

Weber envisaged the consequences of paying lower wages for given skill levels. The deviation is made if the saving is greater than the resulting increase in the cost of transportation. He assumed the absence of substitution of labour for capital, which was comparatively more expensive, and of the unlimited supply of labour, which prohibited any increase in its cost. The analysis, although providing insight into "industrial location movements", remains limited as other aspects of the labour market are involved in agglomeration phenomena.

3.2.2 Agglomeration and location

Another reason for deviating from the minimum transportation point is introduced: agglomeration economies. It was logical enough that Weber should address this problem, given that he was seeking to understand the formation of large concentrations. Here the deductive method is of more limited scope because the location factors in question are related to the "social" nature of production and cannot be deduced from analysis of an isolated production process.

> "An agglomerative factor [...] is an *advantage* or a cheapening of production or marketing which results from the fact that production is carried on to some considerable extent at one place, while a deglomerative factor is a cheapening of production which results from the decentralisation of production" (Weber [1909/1971[R]], p. 126).

Such economies may be made at one and the same time, beyond a critical stage of production (fixed index of economy), or may vary with the size of agglomerated production (agglomeration economy function).

These economies are net of diseconomies which are related, under Weber's assumptions, solely to the increased land price resulting from increased demand.

Such agglomeration may first be reflected, in the weakest form, by increased output from an establishment, with increasing returns to scale (technical factors, organisation of work) then becoming the mainstay of agglomeration. A higher stage is achieved with the concentration of several establishments in a single place, which means the advantages derived by a single large establishment can be further increased. The main agglomeration factors advanced by Weber were:

- The development of highly specialised technical equipment leading to the creation of independent auxiliary industries. The unit operates better if there is concentration because all plant "remain in *touch* with one another" (Weber [1909/1971[R]], p. 129). Such auxiliary industries in turn attract new firms.

  Machinery can be more readily replaced and repaired when the stock of equipment is large and therefore exceeds the requirements of a single establishment: "the best and cheapest service is to be secured *in town*" (Weber [1909/1971[R]], p. 129).

- Differentiated and integrated development of the labour organisation. Some types of work are so specialised that they cannot be carried out even in large firms. They also form auxiliary firms, this division of labour entailing "social" agglomeration.

- Marketing factors also promote agglomeration: larger scale purchases and sales are more advantageous (creation of raw material markets for providing quality and quantity at the right time and a large unified market for products), which represents not only an individual saving but a "social" saving, "labour or social energy is saved" (Weber [1909/1971[R]], p. 130).

- When these factors allow "the best adaptation of industry to the general economic environment" all the general equipment becomes less expensive for individual firm. Weber defines a "plant size index" for each industry representing potential economies at each stage in the growth of the plant and which represents the tendency of plants to agglomerate at each of these stages. These agglomeration factors tend to push all the firms beyond this stage which determines the scope of the second stage of agglomeration.

> "From all this it should be clear —and, through our references to reality, abundantly clear— in what sense we shall speak of the indices of economy due to agglomeration and of the *function of economy* as being a composite of these indices" (Weber [1909/1971[R]], p. 133).

The "economy function" is a series of single indices which reveal increasing economies per unit output as the agglomeration increases. But empirical evidence shows that the influence of agglomeration factors tails off. This decline is necessarily intensified by the weakening of agglomerative factors ascribable to changes in land price with the size of the agglomeration.

To investigate whether there must be agglomeration and where, Weber uses the technique of critical isodopanes. It may be then that agglomeration attracts individual units for which the individual calculation does not justify agglomeration, when the potential collective gain can "offset" the individual loss. This is exploratory thinking on the conditions for forming coalitions.

As places of cheap labour may be "accidental" agglomeration points, it is not ruled out that the two actions may be mutually reinforcing. The problem must then be re-examined as a whole with transportation costs, population density, etc. for any conclusion to be drawn.

Weber also devoted a section to examining to what extent the results were consistent with reality in order to cast light on the findings rather than to conduct "an inductive verification of these results" (Weber [1909/1971/R, p. 162]). Industries with high value added display a stronger tendency to agglomerate, especially if they are labour intensive; "transport-oriented" industries, if they concentrate, will do so close to their minimum point. The development of the economy tends to increase the value added and therefore the agglomeration force, but this movement is slowed by substituting capital for labour which means more goods have to be transported and increases the inertia of the minimum point.

Palander [1935] and more particularly Hoover [1937] criticised Weber's lack of clarity as to the nature of agglomeration savings as they result from internal scale economies, external agglomeration economies and, more incidentally in Weber, from urbanisation economies. Nevertheless this is an interesting analysis all too often overlooked by his immediate successors.

3.3 From individual location to the location system

In the final chapter of his book, Weber relaxed his assumptions. In the real world, centres of consumption are not given, nor are the locations of workers and their wage levels or the location of raw materials. They result from general interdependence. He postulated that partial equilibrium at one time resulted from a change in the previous equilibrium necessitated by development. He started therefore with an isolated economic system in which the population would occupy a new vacant zone. Different distribution and location layers or strata appear:

- The first, in agriculture, where the population spreads over as wide an area as necessary for agricultural production, according to the conditions of the time. This forms the geographical foundation for the other strata.
- The second stratum, the primary industrial stratum, works directly for the needs of the first. The places of consumption and the sources of raw materials are provided by the first stratum. The first industrial stratum "creates the geographical layout" of a consumption sphere and therefore the basis of spatial organisation. This stratum is further subdivided into different substrata under the influence of the division of labour.
- A second industrial stratum is articulated around the first and with the two previous ones forms the economic system.
- A central organising stratum of traders and transporters and population which only consumes (like officials, free professions persons living on their own private means...). Their location seems less tightly constrained.
- Finally a fifth stratum, dependent on the previous one which is composed of industrial substrata and central organising substrata.

The local organisational substratum is encompassed in the first three as a consolidating element.

The "locational forces" which connect these different strata act from the upper to the lower strata and vice-versa, whereas in von Thünen's theory, the central city is the "unexplained basic phenomenon of distribution of agricultural locations".

However, as Ponsard [1958] observed, in Weber's theory, the background remains the agricultural base and the articulation between the first industrial stratum and the agricultural stratum is intricate because of the spread of the rural population which can only be supplied by urban industrial agglomerations. Weber's attempt at forming a theory of location systems was far from perfect, but it did highlight the interdependence of relations and specified the scope of assumptions in his industrial location model. It opened up the way for a theory of regional systems which was to be developed by Lösch [1940].

4 Conclusion

This analysis has allowed us to highlight the contributions of several German authors to spatial economics by re-situating the contributions of each relative to the others. The point has also been made that "multiple discoveries" may occur within one and the same country, suggesting that there is more to this phenomenon than the language barrier alone.

The analysis also illustrates the pioneering role of highways engineers in this area of German thought, as was the case in France too. Launhardt incontestably deserves to see his name associated with location theory and market area theory, but Weber's thinking, in the area of industrial location and in his attempt to explain agglomerations, is more complete in many ways which extend beyond the scope of Launhardt's concerns. Weber also developed components of an interesting theory of industrial organisation in connection with space which has been well analysed by C. L'Harmet [1996].

APPENDIX

Constructing Launhardt's minimum point

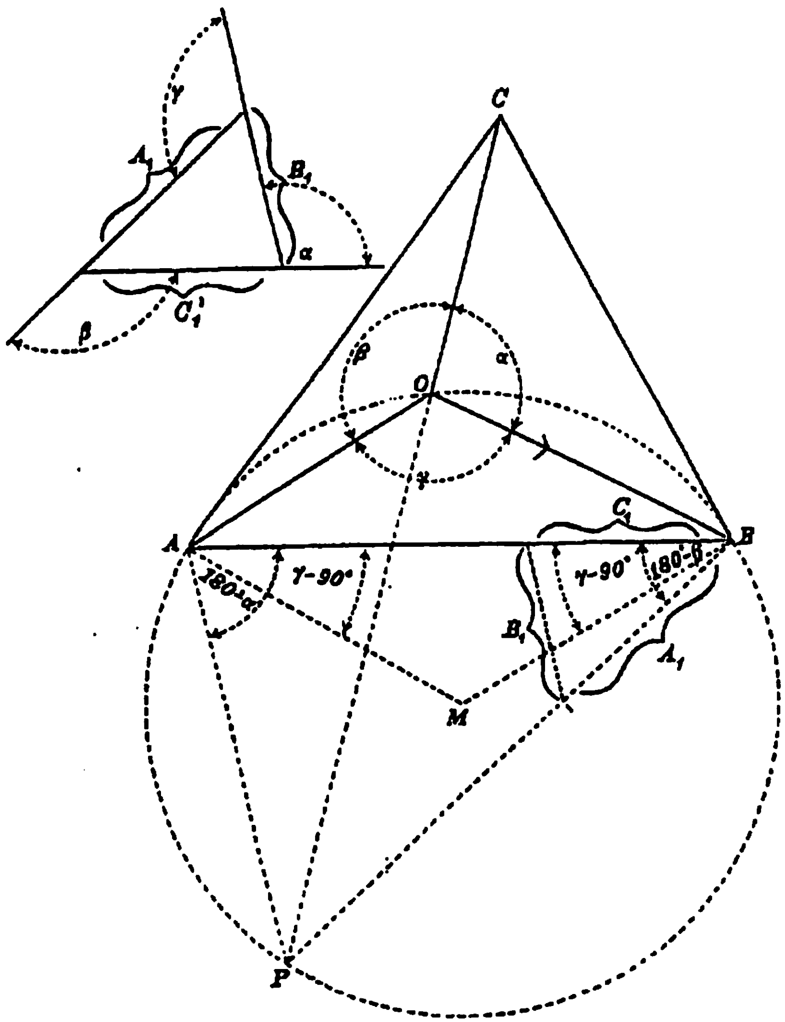

Figure 6: Constructing Launhardt's minimum point (in Launhardt [1872])

A_1, B_1 and C_1 are the costs of transportation per kilometre from A, B and C. Here P is the pole and O the minimum point. The lengths of the sides of triangle BPA are proportional to the transport costs per kilometre.

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