Technological Innovation in Steel Fabrication: Marketing and Production Considerations in the Manufacture of the Johnson Rail

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In the late 1880s, the development of the electric street railway changed forever the contours of urban America. Much has been written about the contributions to the urban transportation revolution of engineer-entrepreneurs like Frank Sprague, Charles Van Depoele, and Elihu Thomson who developed the electrical systems and car motors that made trolley systems a reality and ultimately transformed the spatial dimensions of America's cities [14]. Far less has been written about the technological changes in street railway trackwork that were necessitated by the transition to electric motive power, in part perhaps because it was presumed to involve only a straight-forward application of steel rolling technology common in the manufacture of railroad rails by the 1870s. In fact, standard railroad T-rails were too expensive for small railway systems and not adaptable to the narrow streets and intersections of nineteenth century cities [3].

The market demanded a lighter, more flexible steel rail to replace the traditional wrought-iron strap rails of mid-century horsecar systems, and that type of rail was designed and brought to production in 1883 by the collaboration of Tom L. Johnson, a street railway inventor, operator, and entrepreneur, and Arthur J. Moxham, a young Louisville ironmaster and roll engineer. Between 1886 and 1894, the Johnson rail, a rolled steel rail of girder design with peculiar offset flanges, was used in the construction of most street railways across the country. It was by all accounts the most innovative and most durable rail of its type available on the market. For those cities building electrified street railway systems from scratch, or for others converting their old horsecar lines or cable systems to electrification, the trackwork produced by the Johnson Company, particularly the custom-designed specialty trackwork of cast steel crossings, curves, frogs, and switches, was the standard choice. In terms of design and workmanship, the Johnson Company defined the field and dominated the market [4].

Closer examination of the design and production of the Johnson rail reveals dimensions of technological innovation that have in the past been underestimated or too quickly dismissed. It is the purpose of this article to clarify the degree of innovation attributable to Johnson and Moxham in the early development of street railway technology.

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Technological Innovation Defined

Technological innovation has always been easier to uncover and dissect in hindsight than to grasp in the abstract. Most would agree that it involves a technical contrivance, often too complicated for lay understanding at the time, whose entrance into a market so changed the nature of either products or production processes that it established a new production standard for that market. Unfortunately, the occurrence of innovations of such impact tends to create the expectation that all "true" technological innovations must be accompanied by such dramatic and permanent results. For this reason, innovations which have a somewhat narrower impact may inadvertently be classified as routine contrivances, mere adaptive responses applying common technical knowledge.

What Schumpeter considered a true creative response and Redlich termed genuine (or primary) innovation was that moment in time when the entrepreneur made the decision which brought together elements, all of which were either thinkable or may have existed before, into a peculiar combination that was either not yet conceived or not in existence [7, pp. 30-35; 15; 17]. If measured by this standard too rigidly, the discovery of technological innovation in production fields would be rare indeed, and all other entrepreneurial decisions, no matter how creative, could at best be classified as only derivative, i.e., adapting an original creative response to peculiar production circumstances. Creative adaptations of innovative approaches to local circumstances, accomplished through sequences of small refinements, might easily be discounted as merely a competent mechanic's application of existing knowledge or dismissed altogether as simple imitation [1, p. 208; 15, pp. 287-89].

In application, the boundary between that which can be considered technologically innovative and that which is simply routine adaption is more fluid than we tend to assume. To determine the degree of innovation contributed to a market by the efforts of an entrepreneur would then require us to assess the interactive changes in products, product markets, and production processes in historical context [1, 14].

By way of definition, we can stipulate that innovation involves an action that alters the manner in which existing resources are combined to create greater wealth-producing potential sufficient to bring into production a new product. As such, the innovative dimension of an action is determined by the actual transformation of existing resources, even though the action has been classified as "innovative" because of the impact the decision ultimately had on the market. We must also recognize that the decision is affected by critical non-technical factors as well, such as entrepreneurial organization, production management, business leadership, and product marketing [6, 8, 11, 16, 18].

The degree of innovation represented by an entrepreneur's decision would depend on whether the peculiar combination of elements which resulted from that decision could be considered unique, novel, or "new" in historical context, i.e., in that particular industry at a particular point in time under those particular circumstances. This complicates the assessment of innovation even more, since it requires an appreciation of the state of technical and economic knowledge in context [12]. In most cases, especially in more routine production circumstances, it may be difficult (if not impossible) to develop an appropriate degree of appreciation of the relevant technical, economic and social factors that would have effected such a production decision.

In this we can still rely on Schumpeter's three standards for distinguishing an innovative action from the routine. First, while an innovative decision may be easily understood *ex post* using what had consequently become common knowledge, that decision must be examined *ex ante* through an application of existing knowledge and found to be beyond practical understanding at the time. Second, the innovative decision must shape the course of subsequent products or production in a *permanent* fashion and not merely mark a routine transitional phase. And third, and most critical to this discussion, the decision must be considered with regard to the creative atmosphere, either in the particular industry or in the market overall, from which it emerges and to which the entrepreneur contributes unique catalytic qualities [17, pp. 150-51].

It is in this last characteristic that the entrepreneur's decision must be considered beyond its technical qualities. The innovative entrepreneur is that unusual individual in a market who senses the commercial value of the development of certain technical features in a product and then invents (in the technical sense) the product that possesses those features and/or creates the process that brings it into production. Successful entrepreneurs are seen as able to envision and combine technical, production, and market knowledge and motivated by a high degree of personal conviction and drive. In many cases, a serendipitous market opportunity and unusual access to financial resources are also key factors [1, pp. 298-340; 14, pp. 356-60].

The Johnson Rail

The Johnson rail combined the facility of a L-faced street rail head (which was commonly spiked directly onto wooden stringers buried in the roadbed) with a girder web and base flanges commonly adopted for rolling heavier iron railroad T-rails. The resulting design, offset flanges connected by a vertical web, improved both the stiffness and durability of the rail and, with the adoption of an underset shoulder opposite the tram flange, allowed uniform splicing. The design allowed the rail to be set so neatly into the roadbed that its track could be kept clean and its head did not protrude enough to obstruct other vehicular traffic [3].

Modestly enough, Johnson's patent application only claimed to have brought together disparate elements of existing technologies in a unique fashion to meet a unique market need. The I-beam (girder) structure and rolling processes were common in design and production of railroad T-rails since the 1830s and the L-faced street rail design had been used for decades to accommodate wagon tracking on city streets. Johnson's innovation was to understand how these technical features, distinctive to relatively exclusive transportation markets (railroads and street railways), could be brought together through design.

But design was only half the battle. The question was whether the Johnson rail could be rolled using existing iron rolling technology. Given the state of technical knowledge, the production problems were significant and complex. The Johnson rail was much lighter than railroad T-rails and required unique and uncommon (for the time) lateral drafting of hot metal in the rolling process. The inner tram flange was much wider than its opposite head flange and required radical lateral drafting in the forming passes of the roll sequence.

In three years of experimental rolling in Birmingham and Louisville, Moxham discovered that the Johnson design could not be rolled from iron because its brittle fiber structure resisted lateral drafting [3]. It was commonly considered at the time that wrought iron, with its reduced carbon content, was more ductile than steel and therefore easier to handle in the rolling of complex shapes requiring drafting. This turned out to be true for longitudinal drafting (with the grain of the welded metal) but not laterial drafting (essentially across the grain). At certain temperatures, steel, the more durable but more brittle metal at normal temperature, became more ductile and therefore easier to handle for lateral drafting designs. In all likelihood, Moxham chose to roll the Johnson rail from steel more because of its ductility in the roll sequence than its durability as a product subject to heavy wear.

Moxham's roll design and sequence of passes were not significantly different from the common rolling practices of the day. Complex shapes requiring some degree of lateral drafting were being rolled in more advanced mills. It is clear that both Johnson and Moxham were accomplished technicians in their fields, based on practical experience and innovative market and production sense. In their patents, neither man created "new" knowledge in his field, and neither man claimed to. Rather, they had successfully brought together state-of-the-art technical knowledge from separate (marketing and production) fields into a product that met a peculiar market need. Its production presented a series of complex problems regarding material, structure and roll design that were overcome only by a combination of the unique insight of an experienced ironmaster, perseverance in production management, and significant financial backing [2].

This analysis is consistent with the legal history of patent infringement suits brought by the Johnson Company. The principal Johnson and Moxham patents were both successfully challenged in the early 1890s as not representing true "invention," i.e., new knowledge, but rather representing a common application of (then) contemporary knowledge [9, 10]. As might be expected, respondents argued that Johnson simply adapted a common railroad I-beam structure by changing its head to an L-face design to accommodate street railways and that Moxham simply adapted standard rolling practices to accommodate the peculiarities of Johnson's design.

From the standpoint of technological innovation, the courts accepted the argument that neither man's efforts were particularly innovative; both were simply competent craftsmen accomplishing incremental improvements through repetitive experimentation. This was in practice a standard claim made by respondents in patent infringement suits in both Britain and the United States in the later half of the nineteenth century, usually made successfully several years after the product or process had been patented and in various ways had been imitated to the point of becoming "common" in the industry [1, pp. 194-208; 12, pp. 13-15].

Such a conclusion ignores the sophistication of both market vision and technical craftsmanship exhibited in the Johnson application and the Moxham adaptation, particularly if one considers the time and the state of technical knowledge. But as we can see in hindsight, the innovation reflected in bringing the Johnson rail to market in 1883 did in fact change street rail production (causing many imitators), facilitated the use of heavier engines and cars, and, as argued elsewhere [3], made street railways more politically acceptable to municipal councils.

Conclusion

The Johnson Company has already been cited as a business innovator in the street railway market [13]. What has not been considered to date is the degree to which its market penetration and domination by the 1890s was due to the technical innovation of its product rather than its marketing, distribution, and special service strategies. In truly innovative style, the Johnson-Moxham collaboration allowed a transfer of knowledge (in both directions) between the state of technology and the economy, resulting in what Hugh Aitken termed "an ingenious recombination of items already present in technology's inventory" [1, p. 326]. Johnson saw the application because he was familiar with disparate pieces of technical knowledge and had access to and could communicate with Moxham, who in turn could anticipate production problems. For his part, Moxham's experience on the roll floor and his intuitive sense for mechanical properties of iron at certain temperatures probably contributed to his innovative adaption of roll technology to the offset design and his abandonment of wrought iron in favor of steel.

An assessment of the Johnson rail focusing simply on the technical properties of the product itself, devoid of production or market considerations, might lead to the conclusion that Johnson's invention was a mere adaptation of the common steel railroad rail to an urban context through some form of structural down-sizing. If discounted in this manner, the remaining dimension of technological innovation to be considered would be the decision to replace the traditional wrought iron with steel, commonly interpreted as a question of cost and product durability. Such an approach would radically underestimate the technological innovation of both Johnson and Moxham. Johnson's design clearly ignores metallurgical considerations altogether (which he ultimately left to Moxham) and focuses entirely on improving the product's acceptability in its own market. Johnson's basic concern was to increase the quality of the ride, which he (rightly) saw as the key to building acceptability of street railways as a form of urban transportation. This he achieved by splicing the girder rails with standardized steel plates. As we know, the quality of ridership did in fact create its own demand, and cities all across the country began to build street railway systems.

Moxham's innovative contribution to the Johnson rail was related to metallurgical considerations, but specifically with respect to its drafting properties during hot rolling rather than the product's durability. Only the most restrictive definition of technological innovation would consider Moxham's development of the roll process a simple (albeit masterful) application of common iron rolling techniques to a complex form. In fact, iron rolling itself was (and still is) considered a black art rather than a standard mechanical process [5].

Both Johnson and Moxham would have agreed that their efforts constituted a simple adaptation (or transfer) of knowledge across production and market fields. We know that such a transfer is more uncommon than common, and often has dramatic impact on the market. This contextual analysis reveals that a broader range of technological innovation was involved in the design and production of the Johnson rail and gives us greater perspective on the meteoric rise of the Johnson Company in the street railway market.

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