REDUCTION OR REVALUING IN COST CONSTRAINED DESIGN? -REVERSE INNOVATION CONCEPTUALIZED

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Construction is ripe with examples of cost overrun. Practice is rich on systematic reductions in functionality and ways to avoid scope and cost creep. But research on such systematic reductions are rare. An emerging research literature on reverse innovation propose ways to understand this. Emerging third world markets triggered a geographically oriented notion of reverse innovation. However, second generation conceptualizations include reverse innovation reducing functionality, cost and pricing, and adding new values addressing clients in a new way. Most reverse innovation examples are simple consumer products, but in building, with its complex products, to conceptualize processes and practices of reverse innovation is promising access to new markets. The aim is to explore a conceptualization of reverse innovation of complex built products and gather insights of reverse innovation processes from cases. They exhibit different features and processes, reduction strategies with departure at an (imagined) high end product, appear to be recurrent in construction. Once faced with a potential, estimated cost overrun some designers would follow an ad hoc strategy of reduction in functionality until the cost target is reached. However proactive strategies, such as innovative substitution, offshoring of design work, shift of suppliers, and global sourcing are possible.

Keywords: costs, value management, innovation, reductions

INTRODUCTION

There are many, also contemporary, examples of project budget and time overruns. In the 2016 UK construction excellence report, 32% of the reported projects experiences cost overrun and 49% time overrun (Construction Excellence 2016). In some cases, such overruns are accompanied by commonly accepted scope creep, presented as improved functionality and consented to, or even celebrated, by stakeholders. In other cases, overruns lead to repercussions, legal, financials or reputational. However, in some "third type" cases it is clear, even early on, that overrun just cannot be tolerated. Budgetary frames in such cases cannot be moved. They might be regulated by law, as in social housing in Denmark, or their politically negotiated character in some cases cannot be "unfrozen". In such "third type" projects, stakeholders possibly adopt different paths of developing briefing, design and producing buildings. The paths of various types of reductions.

The research interest of this paper is what characterize such brief, design and production reductions? If systematic reduction is carried out - for example by going through each

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design area; architecture, structure, HVAC etc., to find functional and cost reductions, then when is such systematic reductions innovation, do they lead to new value or revaluing?

The theoretical framing is reverse innovation (Von Zedtwitz *et al*, 2015, Winter and Govindarajan 2015) and reverse engineering (Messler 2014, Lee *et al*, 2016). Reverse innovation is defined as reducing function, cost and price, but also adding new value for the customer. Departing from mass produced consumer goods and moving into complex product-service as notion for building projects.

The paper discusses two empirical cases, selected for their content of reverse innovation. The projects are a public school and a non-profit social housing student's accommodation, for short a school and a dormitory. The cases are developed through revisiting published case studies of the two projects. The dormitory project encompasses 66 new student accommodations. It was designed according to German norms for passive houses. It was built at 7.35 million euros within the maximum cost of 2,485 euros/m2 set by Danish Government allowed cost for social housing construction. Which is a strict frame in the context of Danish building costs. The school project was a renovation of a relatively old urban public school. The primary and secondary school and its municipality participated in a national architecture competition and was renovated in selected areas such as the hall, the primary school premises, and the library at 3.75 million Euro. The constraints of this project originated from the municipality budget priorities.

The contribution of this paper is to identify reverse innovation of complex products as a research gap and commence conceptualising how reverse innovation can be understood and used on buildings as epitomic cases of complex product services.

The structure of the argument is as follows. As the method outlines the spine of the knowledge production carried out here it is presented first. Then follows the framework of understanding accommodated to answer to the objectives of the research. The two selected cases are first described and then discussed in the light of the objectives and the theoretical concepts. This allows the argument to draw a set of conclusions and implications.

METHOD

The research questions invite the adoption of an overall paradigmatic placing in interpretive sociology. To commence conceptualising reverse innovation in a building sector context, the paper draw on innovation concepts, reverse engineering and reverse innovation. As many concepts of reverse innovation focus of geographical relocation, the conceptualisation turn to the few looking at complex product services. This conceptual endeavour is still early explorative in character. Illustrative cases from the building industry in Denmark was searched for, that encompassed reduction in functionality to meet low resource customers. The two cases selected come from a small group of contemporary and previously researched cases. These include large greenfield hospital projects (2), public school projects (3), sustainable buildings (2), and infrastructure projects (1). One school and one sustainable building, the dormitory, was chosen because the briefing, design and production processes were best documented, i.e. quite pragmatic reasons in correspondence with the exploratory stance of the paper. The other cases are used as backdrop for the discussion.

The dormitory project encompasses 66 new student accommodations built from 2006 to 2009 (author reference). It was designed according to German norms for passive houses and built within the square-meter frames of Danish social housing. The project also included testing of a renewable energy technology. It is the main building that is in focus. The process was followed from to start to one year after commissioning, i.e. from 2006 to 2010. The activities in the design and planning process from November 2006 to August 2008 is of special interest here. Process mappings from records of 31 different meetings was carried out in this period. These mappings focus on innovation, process and product topics. A year after finalising the dormitory, an occupants' questionnaire was sent out, and 18 occupants responded out of about 66 possible. The questionnaire covers perceived value of the clients.

The school study is a longitudinal study of the processes from the initiating architectural competition (1995) until the second renovation has been carried out (2005). Qualitative interviews have been carried out in three rounds; in the start, in the middle and in the end of the processes. Some 16 interviews with stakeholders have been done, each of 1, 5-2 hours length. Most was interviewed in the start. In the middle and end, only active stakeholders were interviewed. Also, document analysis was used. The early phase was a joint process were a ministry and three schools participated.

To reanalyse these two cases the author reread case descriptions and analysis done previously (references to be inserted). Moreover, the author could draw on more detailed knowledge of the cases from previous collaboration with authors and others in the two cases.

FRAMEWORK OF UNDERSTANDING

The framework combines approaches to construction innovation, reverse innovation and reverse engineering.

Construction Innovation

The concept of innovation originates in economic theories about growth. However, a host of studies and approaches have proposed to add to or reconceptualise this understanding (Orstavik *et al*, 2015). Most famous is probably the center for the sociology of innovation in Paris, with profiled contributors like Callon and Latour proposing actor network theory as understanding. A position emphasising the process of innovation. Here we more modestly follow Orstavik *et al*, (2015: 4) proposal of understanding innovation as "humanly created changes in established ways of creating value". Innovation are often exercises in a tension between value and cost and value propositions by stakeholders tend to get mediated through cost calculations (Van de Ven *et al*, 1999). Also innovation is "measured" or identified through a contextual argument (Tidd and Bessant 2009), underlining that innovation can improve competiveness in one context, even if well known in another, something which is in turn exploited in the geographical version of reverse innovation.

Reverse and Value Engineering

Reverse engineering and value engineering are quite mature concepts, which both occasionally have been assigned quite cynical features. Reverse engineering being a tool for industrial espionage and value engineering for a strong focus on cost reduction. Messler (2014:1) understands reverse engineering as

> …a powerful technique, process, method, and means for creating a design…. It is, quite simply, mechanical dissection or "teardown" of mechanical, electrical, electromechanical or mechatronic, and, occasionally, biological entities.

Teardown and dissection are central concepts and Messler mostly take point of departure is a physically realised product that can be disassembled to learn about its design. Reverse engineering make use of CAD models of the product (Durupt *et al*, 2014, Lee *et al*, 2016). Reverse engineering is linked to and overlapping value engineering and value management. All pointing to the "plastic" shaping of the value of objects along with their physical shaping (Messler 2014). However for Messler it is the technical "read off" of the physical product which is important less than the costs. And functional reductions does not enter his conceptualisation. Value engineering is in turn, according to CIOB (2017) used to solve problems and identify and eliminate unwanted costs, while improving function and quality, thereby integrating technical functionality, value and cost. The aim is to increase the value of products, satisfying the product's performance requirements at the lowest possible cost. The central methodology is to analyse the component parts of a product in terms of its function, searching for ways of providing the (same) functions at a lower cost; and then to verify the economic and technical feasibility before putting it on production. In construction this involves considering the availability of materials, construction methods, transportation issues, site limitations or restrictions, planning and organisation, costs, profits and so on, according to CIOB (2017).

Reverse innovation

The definition of the reversal of innovation initially denoted a product or service developed in a developing country that was then at a later point in time or immediately, introduced in an advanced country (Zedtwitz *et al*, 2015). This approach involves quite some focus on marketing in the advanced country (Hussler and Burger-Helmschen 2016, Tournois 2016). The first definitions of reverse innovation thus simply focused on geographically reverse movements from emergent to advanced markets. Zedtwitz *et al*, (2015) extended this and defined reverse innovation as "any type of global innovation that, at some stage during the innovation process, is characterized by a reversal of the flow of innovation from a developing country to an advanced country, and that is eventually introduced to an advanced country's market". However going beyond the geographical conceptualisation second generation definitions include reverse innovation with new values of the product or service addressing potential clients in a new way (Hussler and Burger-Helmschen 2016, Winter and Govindarajan 2015). The potential for reverse innovation is twofold. First it lies in the rise of developing countries as emerging markets, were medium and lost cost products can find new costumers (Zedtwitz *et al*, 2012). Second it relates to disrupting western and other developed markets by adopting reverse innovation approaches. Failure from Western companies to grasp the economic, social, and technical contexts of emerging markets can potentially threaten incumbent companies in the west. Winter and Govindarajan (2015) claim that experience has shown the following five failures are prevalent: Trying to match market segments to existing products, trying to reduce the price by eliminating features, forgetting to think through all the technical requirements of emerging markets, neglecting stakeholders, refusing to believe that products designed for emerging markets could have global appeal.

Examples of reverse innovation of complex products

Most examples of realized reverse innovation are consumer goods such as mobile phones. Reverse innovation of complex products is thus a research gap. But products of medium complex range also surface such as passenger cars; the Fiat 147 (Zedtwitz *et al*, 2015), the Renault Logan (Winter and Govindarajan 2015) and the Tata Europe (Winter and Govindarajan 2015). The Logan for example, is a car that Renault designed specifically for Eastern European customers, assumed to be price-sensitive yet demanding value. The Logan cost only $6,500, but offered greater size and trunk space, higher ground clearance, and more reliability than rival products. To obtain a low price, Renault used fewer parts than usual, and manufactured it at low labor costs in Romania. This reverse innovation combines geographical and value reversal. A number of projects have followed Govindarajan and Sarkar (Govindarajan 2010)'s idea of a $300 house for low resource groups in developing countries (Gross 2010). Thus, the picture is that the upper market of complex products is less covered by reverse innovation efforts. Here the potential would relate to systematically reducing functionality to address needs in a lower resource market.

The process of reduction might be carried out in direct collaboration with customers as value creation is with complex products. Xu and Xu (2016:62) provide three examples in reverse innovation processes of complex products i.e. "pure low temperature waste heat power generation technology", "large coke oven technology", and "horizontal well drilling technology". These complex products were gradually developed by Chinese companies, relying on reverse innovation from advanced markets technologies. However the complex product-services are delivered in an emerging market context and not to advanced markets. And Xu and Xu (2016) tells little of the processes of realizing these reversed product services. Complex product-services, or at least the value of complex product- services are coproduced with the costumer (Løwendahl 2000). The producer-customer relation thus has a networked character in complex product-service context in contrast to marketing for mass markets, which is often highlighted in reverse innovation (Hussler and Burger-Helmschen 2016), Tournois 2016).

Apart from Xu and Xu (2016) the literature on reverse innovation in complex product-services is scarce. From writings on buildings as complex product service it is well known however, how multi-aspect design can be complex and emergent (Gann and Salter 2000) and lead to over engineering (Winch 2002) and cost and time overrun (author reference). Along with Zedtwitz it is suggested here, that reverse innovation can occur in any of the complex product-service realization steps, or as Zedtwitz (2012:12) specify it, four characteristic phases: concept ideation, product development, primary target market introduction, and subsequent secondary market introduction. As noted by Subramaniam at al., (2015), Zedtwitz *et al.*, (2015)'s conceptualization reveals that a number of possible reverse innovation flows are still uncharted.

His 16-type model mostly cover mixes of advanced economy (A) and developing economy (D) interactions, but also involves an AAAA version where all four phases are placed in advanced countries. This is however portrayed as old-fashioned. In this present framework however it is proposed to focus innovation activity and value creation, meaning that in principle reverse innovation can occur in the AAAA model as well. And that this is instrumental, given the closeness to the customer in complex product-service design such as building design. Given the growing use of engineering offshoring in building (author reference) it is not unlikely that reverse innovation of buildings also might involve geographically displaced elements, probably during design, meaning following an ADAA model.

Framework

Reverse innovation in complex product-services departs from a reverse engineering understanding of technical "read off" of functional product features and systematic reductions. Complex product-services, or at least the value of complex product- services are coproduced with the costumer. While the geographical location of any step of the realization of a complex product service is in no way de-appreciated here, the definition is however that reverse innovation can create change and value in all steps in this realization also independently of geographical de-location. Reverse innovation activities in principle encompasses co-design with users, reconceptualising, reduction of functions, refinancing, changed marketing. One might talk about weak and strong reverse innovation. Weak covers those humanly created changes that do systematically reduce function and cost, which therefore can be understood as innovation in a concrete context. Strong reverse innovation is when the exercise of reduction leads to improvements of the value/cost balance by departing from pure reduction and introducing new creative, innovative solutions to meet the cost regime.

The Dormitory Case

The project was initiated by the non-profit social housing association Fruehøjgaard. This association had participated in innovative projects before, and it wanted to contribute in 2006 to the development of sustainable buildings still maintaining cost efficiency. This client had a number of visions and ideas for the project, encompassing use of passive house design, prefabrication, realizing a good indoor climate and a collaborative process of partnering and lean. The architect was selected through a competition amongst five competitors. This led to the selection of an architect and consulting engineer. Shortly after the brief design commenced. As the project was carried out within the public governance of social housing a strict budgetary control of design and production cost was implemented. Also, a confirmation of the allowed frame was sought through a meeting with the responsible ministry.

However, in the subsequent period the budget control failed and there were numerous dialogues over the contracts. This led to a budget status made in May 2007, which showed a deficit of 675 000 Euro or roughly 10% of the budget. This budget was scrutinized entry by entry and an action plan was elaborated. 135000 Euros in cost reductions was found, yet in September another status revealed that the deficit had reached 21%. This predominantly occurred due to the primary building component of the structural elements, the bath cabins and the building envelope which compared to the ministry benchmark figures cost the double. This links into another central aim for obtaining a compliance with government demands was through using prefabricated elements. A supplier of bath cabins was contracted early in 2007. Another Danish manufacturer of prefabricated modular building envelope elements participated in the early phase in 2007. The manufacturer developed a prototype of a room module, but the calculated cost was too high and the project was forced to shift supplier. In autumn 2007 the project had allocated costs to these prefab elements that were a serious burden for the budget.

A shift was made to using façade elements for a passive house building envelope, using a German prefab manufacturer, a collaboration that commenced in November 2007. This created a saving on structural elements of some 350 000 euro. Also, a German windows supplier was chosen. This can also be seen against the background of the status of the Danish market for building components at the time. In 2007-2008 it was understood that no Danish component manufacturer could live up to the passive house standard. By December 2007 a deficit of 55000 Euro was reached and preliminary accepted. The designing demand of living up to passive house standards triggered three iterative rounds of energy calculations. The early process of involved calculations by the engineering consultant using Danish energy calculation software. However, in early 2007, calculations still showed a net heating demand of 21 kWh per m2 per year higher than the standard 15 kWh. By July 2007, the design work was able to meet the certification demands. Third, as the clients' demand was a certificated passive house, it was decided to ask for consultancy from the Darmstadt experts. This third round of calculations showed that the third demand of total specific primary energy 120 kWh per m2 per year could not be met, primarily due to differences in definitions. But the project met its cost goal. In the project's calculated final balance, the total cost was set at 7.35 million euros. This equals a cost per square meter at 2,300 euros, or 92.4% of the maximum amount of 2,485 euros/m2 set by the government. This was made possible by the mentioned budget reduction exercise and by several of the participating companies that saw the project as innovative and were willing to put aside part of their costs in terms of hours spent, as they viewed it as an investment in future knowledge and products. Prefabrication was another goal that was met. The degree of prefabrication is some 59%. The passive house certification was obtained a year after occupation.

The School Case

The school participated in a national architect competition on "the public school of the future". The three participants in the competition was chosen by the ministry of education with the aim to find schools representative of schools in general in Denmark. The school chosen here is a relatively old school placed in an urban area with limited possibilities of enlarging its estate. The school aimed at a considerable renovation. It has been granted a smaller budget as part of the municipality school plan, but aspired to use the architect competition as lever for enlarging the budget for renovation. To participate in the competition the municipality signed a contract with the ministry, which committed the municipality to invest funding in the project. The conditions for the competition were published and involved amongst other things an obligatory participation in the competition teams of a didactical expert. The competition was initiated and finalized over a period of five month.

The ministry and the municipality had five meetings to prepare a text program for the school. This was a tough process as the school representatives and the municipality started from scratch and had to deliver quickly. Subsequently the architects' proposal was developed over 1-2 months. The competition follow standard rules for Denmark and involved architecture experts, an independent surveyor contracted to evaluate the cost of the projects and other stakeholders including representatives of the municipal board (politicians). It there quickly surfaced that there was a mismatch in expectations and agreements. Most projects presented cost up to 8 times more than the municipality had allocated.

The competition was framed by the ministry and led by the architects' experts however and price did not enter as criteria, to allow for creativity to blossom. The project was subsequently split in two to accommodate the cost frames of the municipality. The rebuilding of the gymnastics hall was realized as designed, yet was a small project. Whereas the other part was reconceptualised. The process of this project became long and even halted over several years. When funding for the second part arrived the architect and schoolmaster selected elements from the competition project. They choose to focus on the hall, a central meeting point yet a passive area. Here a service counter, a café and the school library was incorporated into the hall. A theatre hall was created and cellar facilities equipped for receiving the youngest pupils. The theatre is a new element compared to the competition project.

DISCUSSION

The dormitory process features a client with many ambitions and visions, but still having to act within a detailed public governance. This framework triggers an active and conscious search for innovation that can aid in combining the contradictory framing. The cost frame was accepted as a thoroughgoing condition for the project. The client in this manner decided not to circumvent it by financial innovation that could have orchestrated more funding (Åkerström and Pors 2017). There are actually examples of combining social housing projects in Denmark with for example commercial buildings to do such innovations, combining two clients. The process that emerged has a more or less constant focus on reducing costs. The choice of foreign suppliers is a direct consequence of the combination of a strict cost level and a high demand for value through quality functionality.

Thus, windows and façade modules was purchased in Germany. Such reverse innovation does not reduce functionality. The project did comply with many if its goals. It reached its cost goals, yet only after a rigorous reduction exercise. It received a passive house certification thereby living up to a central product demand and realizing a central goal of innovation. However, the perceived value by tenants was more problematic as the indoor climate did not live up to expectations. And the consulting engineers participating restricted their hours billing to the project to maintain its feasibility. In the public school project the reverse innovation involves first splitting the project in two to accommodate the cost frames of the municipality. And in the second round picking and choosing from the larger competition project. In the first part the gymnastics hall was realized as designed, yet was a small project. Whereas the other part was reconceptualised.

In the second part, a few elements from the competition project was selected and a theatre hall added. This approach was possible because the original project did not involve deep structural changes of the school building, neither was the project a strongly integrated unity. It thus echoes proposals of using modular design in reverse innovation. The process of this project became long and even halted over several years. The school master being the only thoroughgoing person. This also enabled the pick and choose approach. And can -if strongly interpreted- be viewed as a reorientation of the target group for the product, the school master more or less monopolised the project in the end. This can be compared to the repositioning of market and marketing in reverse innovation. In terms of value creation for the customer, the interest groups in the customer constellation is split in their evaluation of the result. The central actors are on the other hand disappointed over the lack of realization of the designed project Other stakeholders, accept the result and further stakeholders such as the teachers are not satisfied. The case shows that it is not given that reverse innovation will occur in the design phase. Here a post design phase is entered where central actors "pick and choose" from the design.

Systematic reduction?

The two cases are common in their lack of direct systematic reduction (no use of reverse or value engineering) beyond practices resembling bookkeeping where the actors go through entry by entry their budget to find possibilities of reduction, which was used in the dormitory case and the functional split of major parts of the product used in school case, supplemented with the pick and choose approach made possible by the renovation project of the school. In this manner, the two projects represent each their extreme in the rule of thumb strategic dilemma of "cut on the surface evenly across functional areas or cut in depths, one functional area out". These two strategies are common knowledge and common sense, the first even having a popular nick name "the forage harvester method". Sehested (2008) is told by her interviewee architects, that these reduction situations are recurrent, a similar finding to that of the author's hospital project, where one interviewee even claimed that reduction approaches must be accommodated to the single project special characteristics.

Innovation?

The use of reductions in the two projects lead to innovation. In the dormitory, the use of another supplier of the building modules is at a time a considerable saving and a process/product innovation. Also, several elements of the school project add new innovative elements to the school's way of operating (i.e. the design of the primary school area, the detailed design of the hall). The analysis of the cases first show that "non-geographical" reverse innovation occurs. However once established that the cases predominantly operate in a single context of high resources it can be noted that the dormitory case do utilize the differences in price and experiences Denmark- Germany in terms of supply of building components for passive houses. Moreover, other cases not discussed here, feature cost reduction through offshoring of design work, insourcing of migrant workers and other socio-geographically based practices.

CONCLUSION

This paper set out to explore how reverse innovation might be relevant for a complex product- service such as building projects. This was done asking what characterize brief, design and production reductions. If and when systematic reduction is carried out, then when can such systematic reductions be understood as innovation? Innovation was defined as change that create value and reverse innovation defined as reducing function, cost and price, but also adding new value for the customer. The paper then analysed illustrative exemplars of reductions in brief, design and production of building where a budgetary and/or political framing meant that scope or budget expansion was not possible, also asking whether systematic reduction was carried out through scrutinizing each design area of the building to find functional and cost reductions, then is such systematic reductions innovation, does it lead to new value or revaluing? The theoretical framing used drew on reverse innovation literature, arguing that reverse innovation can add value to customers without having to use geographical "transplantation" from high resource to low resource areas/continents of the world. But using reverse engineering approaches complex product-services can be realized.

The paper presented and analysed two illustrative empirical cases, selected for their content of reverse innovation. The projects were a public school and a non-profit social housing student's dormitory. The analysis of the cases first show that "non-geographical" reverse innovation occurs. This type of innovation has occurred in Danish context of lower resource clients in need of as much value adding functionality of the product service offer they could get at an affordable price. In the dormitory case the budget frame triggered innovation and acted as a thoroughgoing frame, and led to reverse innovations, but also to sustainable innovation and process innovation. The school case exhibit a far more ad hoc approach in circumventing and addressing limited resources. The cases share a lack of direct systematic reduction beyond bookkeeping approached scrutinizing entry by entry used in the dormitory case and the functional split of major parts of the product used in school case. The implication of a possible future role of reverse innovation is to commence a learning and search process for approaches and procedures that can accommodate strict budgetary frame. In a global perspective, the use of reverse innovation have major impact on possibilities of realizing welfare. But also in the western hemisphere, resource differences prevail, that justify that building professionals should be able to realize projects for low income groups. In the present context of Scandinavia a strong paradox of an overheating building sector, rising material prices and large low resource groups in society pose threats to social stability.

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