CONTROL IN AN INTERNATIONALISED LABOUR PROCESS:
ENGINEERING WORK IN THE SEMICONDUCTOR INDUSTRY

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1. Introduction

Work in globalised capitalism is developing now increasingly through spatially complex relations and dynamics. The labour process theory analyses now for several decades how the interest of capital are affecting work through systems of control (Friedman 1977, Edwards 1979) and dynamics of de-skilling (Braverman 1974). With its high focus on the local labour process organisation the labour process theory is able to take its analysis onto a very detailed and informed level. Although various labour processes around the world have been put though such an analysis the perspective has always been a very local one. The international level of the production process emerges at most marginally and is not integrated as a fundamental characteristic of capitalist production. It has been noted by various authors (Ranie 2010, Thompson and Vincent 2009), that such an expansion of the labour process theory towards a larger political economy perspective can be of help in overcoming the organization-centric perspectives of the last decades (Thompson 2009). This article attempts to at least partially answer this call through analysing the labour process of engineers in the semiconductor industry in a very focused case study.

The electronics industry in general and the semiconductor sector in particular has been the vanguard of internationalisation and industry restructuring towards vertical specialization (Lüthje, Hürtgen, Pawlicki & Sproll, 2012). Labour intensive parts of semiconductor manufacturing were offshored to South-east Asia for the first time in the late 1960s, with more technology intensive wafer manufacturing following in the early 1980s (Angel 1994). While some semiconductor companies began to build up product development capabilities in developing markets in the mid-1980s, the industry wide internationalisation of innovation started in the late 1990s. This long history of internationalisation of manufacturing and development renders the semiconductor sector very interesting the analysis of the dynamics of an internationalised labour process. Regions hitherto regarded as peripheral are integrated into the global networks of development as a new phase of internationalisation is unfolding. With some of the development centres existing for many years it is possible to analyse their function within company wide networks after the initial phases of establishment, that offer only limited insights, have been successfully completed. Eastern Europe specific industrial history renders it especially interesting for the analysis of global integration.

Questions regarding the development of the international division of labour and the labour process that is unfolding within this process cannot be answered anymore referring to simple dichotomies. The international division of labour is increasingly complex, with new
locations, new functional hierarchies and a highly dynamic development. Traditional concepts of centrality and peripherality are challenged by empirical evidence, as are assumptions about the importance of new locations and the technical and organisational capabilities of local engineers.

2. Control in the internationalised labour process

2.1. Layers of control

Barrett (2004) noted that management strategies change over time as a consequence to industry and economy wide developments. This has to be extended by the notion of space. Friedman (1977) formulated already a crude model of spatial differentiation in work organisation in which central locations were characterised by higher levels of autonomy whereas management used direct control in peripheral locations. However, in the current situation a simple deduction of managerial strategies from particular geographic locations is not possible. Especially with the highly specific labour process of engineers the relations become much more complex. As we will see the organisation of the labour process of chip design engineers in Eastern Europe resembles in many ways the labour process of engineers in central countries.

To be able to analyse the organisation of engineering work within Global Design Networks (Ernst 2005) of the semiconductor industry, Friedman’s (1990) framework based on managerial strategies focused on maintaining authority over labour is useful. Friedman (1977, 1990) argues convincingly that managerial control strategies are the primary dynamic influencing the organisation of work. The notion of managerial strategies is helpful to describe how the labour process is being organised as the specific actions of management as well as the particular organisation of work cannot be simply deduced from structural characteristics. In this view management is an agent that reacts to changes on the levels of markets, technologies as well as resistance from workers. The environment in which managerial strategies evolve is first and foremost the firm with its peculiar production that is driving a specific labour process. This production process is integrated in a wider environment of the competitive landscape for the firm and the technological dynamics that affect the outcomes of worker struggles. As the semiconductor industry is fully

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1 Friedman’s initial model (1977) of managerial strategies was criticized regarding the simple dichotomy as well as the level of rationality in the choice of a specific managerial strategy (Nichols 1980; Littler 1982; Thompson 1983) leading him to counter the critique with a more elaborate framework.
internationalised factors such as the position of a company in the global design network set certain limits to managerial strategies. Furthermore, ability to secure enough engineering talent as well as the reluctance of engineers to change workplaces are decisive factors for the definition of managerial strategies in this region.

Based on Storey (1985) Barrett (2001, 2004) regards Friedman’s managerial (1977, 1990) strategies of direct control and responsible autonomy to evolve into systems of layers of control. In this view control strategies are not exclusionary single practices from the continuum between control and autonomy. Rather ostensibly opposed strategies coexist and form complex control structures. In this layered control system various strategies are used separately and simultaneously to control the labour process (Upadhya 2009). This can translate in a continuous succession of alternation between control and autonomy as in the system of milestones, where phases of autonomy are followed almost without exception by high levels of control during the closure of a particular milestone. Simultaneity of diverging control practices is found often in the organisation of international interfaces within the labour process. Highly standardised and formalised procedures are used by management to set up and control such critical interfaces. However, simultaneously the engineering labour process is organised sufficiently autonomous to be able to cater for the contingencies that emerge in the day to day operations. Within the engineering labour process these layers of autonomy and control form a dialectical relationship where management needs to balance autonomy and direct control in such a way that both creativity has enough space for development and profitability can be achieved.

Following Friedman’s (1990) break down² of the managerial strategies, as well as the labour process itself, this paper’s analysis of the layers of control is based on the categories of task organisation and control structure.³ Task organisation within Global Design Networks is dependent on the position and development of a particular design centre. Engineers working in a centre organised as a extended workbench are passive pendants of a centralised labour process receiving detailed work packages with technical and organisational instructions. As engineering work is then reduced to the automatic implementation of specifications such an organisations tends decisively towards managerial strategies characterised by direct control. The ability to influence both the technical as well as organisational level of task organisation

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² Friedman (1990) developed overall four categories. The other two categories are lateral relations and labour-market relations. The confined space of this articles does not allow to expand on them.

³ Task organisation includes work request, scheduling as well as tools. Control structure involves procedures, monitoring as well as evaluation.
becomes a central focus of the analysis. This ability is linked to dynamics of intra-organisational international divisions of labour and processes of upgrading.

Within the engineering labour process which is characterised by high levels of autonomy and currently most often organised as project work, milestones become central tools for both the managerial control as well as standardisation processes. The granularity of milestones and deadlines in project work organisation have been analysed as instruments of direct control (Barrett 2004, Upadhya 2009). A finely grained milestone structure is regarded by engineers often as confining both their creative capabilities as well as scheduling autonomy. In a situation characterised by a highly volatile workforce a system of finely grained milestones can play also the role of knowledge management, as it provides management with many points at which engineers need to deliver completed tasks and documentation that can be put to use in case the respective engineer leaves the company and abandons his part of the project. Milestones can be analysed as practices of direct control, as they define precisely the deliverables and the dates these are due. However, the question is how these milestones are defined. A dialogical definition of milestones based on the experience of engineers tilts this practice more into the direction of relative autonomy. But in light with Burawoy’s insights (1979) we have to be aware that such a integration of workers into managerial tasks despite rising the level of autonomy is integrating them further and providing the basis for the reproduction of control structures. Within the system of milestones engineers can act relatively autonomously and manage their time and tasks on their own. This is rising the subjective levels of work, especially skills like time management as well as experience.

Monitoring of labour is an important part of the control structure. Engineering work, with its many phases of creative and immaterial work causes problems for strictly direct control strategies. It is not possible to measure the invested work effort required to come up with a solution for a technical problem. The focus shifts more towards the work results translating into framework systems such as milestones and/or deliverables. However, to be able to estimate the progress in between the particular milestones monitoring has to take place both for organisational as well as quality reasons. Monitoring in an internationalised labour process is often making use of standardised and formalised processes of reporting. Shifts in the international division of labour driven by processes of upgrading such as the localisation of project management shift monitoring to a more personal monitoring, while simultaneously expanding the autonomy of engineers as formalised reporting processes can be minimised.

Technical and time autonomy as well as strategy autonomy (Barret 2004) can be used to group dynamics from several categories of work activities. Managerial strategies are based on
layers of control that do not operate in a discrete way over the whole labour process. Rather managerial strategies have lateral affects within the labour process. Technical and strategy autonomy are crossing both task organisation as well as control structure and lateral relations. The ability to define relatively autonomously how to tackle a predefined problem, or technical autonomy, needs a specific organisational framework. With technical autonomy the engineer has some degree of control and discretion over the development process, at least over the part that he is responsible for. Although design methodologies and flows, as well as quality management limit tool choices as well as the way the result has to conform to technical requirements, with a high level of technical autonomy an engineer still needs to develop the idea of how to resolve the problem on his own. The implementation of this resolution, especially the specific sequencing of the various necessary steps, lay in his discretion. Technical autonomy is linked to the ability to monitor the labour process by the management. The higher the level of technical autonomy is the lower the detail of control can be. The monitoring of work, especially through the evaluation of goals that were predefined becomes more important. The characteristics of the process leading to the definition of project goals and schedules are important to understand how autonomy is being injected into the labour process.

Time autonomy is the ability to structure one’s own work. Milestones and low levels of automated monitoring, as well as the ability to influence the scheduling are the most important aspects from task organisation and control structure that affect time autonomy. The granularity of milestones defines broadness of time autonomy. However, the specific organisation of the labour process and the hierarchies based on this organisation can have a decisive influence on time autonomy. Contingencies within the development process, based both on organisational as well as technical issues, can prolong the required design time extensively but do not alter the initial often dialogically estimated project deadline. Sequential work organisation coupled with deadlines and contingencies can lead to a fundamental lowering of time autonomy for engineers located at the end of the process.

2.2. Upgrading and integrated teams

Capitalist production is organised on the global scale through a continuously evolving international division of labour. Initially, in the 1970s, critical scholars analysed the evolving internationalisation as resulting in a quite static as well as self-reproductive hierarchy (Hopkins and Wallerstein 1977) asserting a specific complementary division of labour (Fröbel et al. 1980). The idea of a complementary division of labour was also used to analyse the
integration of Eastern Europe into the internationalised capitalist production (Berger et al. 2001). However compelling and accurate this analysis was for the initial phases of capitalist internationalisation, the further the international division of labour evolved the more did it call for a different perspective that allowed to analyse the emerging empirical evidence of dynamics and differentiations. Gereffi’s (1994) Global Commodity Chains and his subsequent Global Value Chains (Gereffi et al. 2005) concepts shifted the focus of analysis of development towards the firm and introduced learning processes driven by the cooperation between firms. Indicating the lack of considerations regarding local characteristics in both concepts (Bair 2005), Henderson et al. (2002) developed the Global Production Network approach and developed a more dialectical and historical perspective on the development of the international division of labour and how it is shaped through the integration of various localities.

All of these approaches were developed with regards to the internationalisation of manufacturing, as it was the first part of production that experienced extensive offshoring dynamics. The semiconductor industry saw first overseas manufacturing operations in low-cost countries already in the late 1960s (Angel 1994), with increasingly capital intensive manufacturing being offshored to the same locations since the 1980s. Since the mid-90s increasingly R&D related jobs are being offshored throughout the semiconductor industry to the so called peripheral countries, or developing economies, such as South-east Asia and Eastern Europe. With the fundamental economic problems of semiconductor manufacturing and development, most importantly the exploding costs for wafer fabs as well as technology and product development, the dynamics of offshoring innovation work to so called low-cost locations has increased in the last years in the industry (Ernst/Lüthje 2003; Lüthje/Pawlicki 2009). To be able to analyse these dynamics in the international division of labour Ernst (2005) put forward the concept of Global Design Networks. These networks are organised around one focal company, or in the case of intra-organisational networks around the central R&D location. This centre is able to set and enforce specific organisational and technical standards that all participant must follow. In their initial phases intra-organisational Global Design Networks are often based on complementary divisions of labour, where design centres from so called low-cost locations are assigned with low-end and repetitive parts of the design process that can be easily offshore and monitored. However, both learning processes, overall problems of semiconductor economics as well as local characteristics generate an overall pressure that can result in processes of upgrading. Upgrading has effects on the organisation of the engineering labour process.
Global Value Chains, Global Production Networks and Global Design Networks approaches agree that processes of upgrading are a dynamic that is inherent in the internationalisation of capitalist production. Most important for upgrading are the knowledge flows and learning processes that occur within these inter- and intra-organisational networks. These are necessary for the technological and organisational adaptations called for by the set standard of the central company. These adaptations are often bolstered by lead companies though organisational as well as financial assistance. Similarly within intra-organisational networks new locations constantly need to work on their capabilities often trying to use locally available resources. Besides purely capability oriented processes the build up of trust is necessary to lower transaction costs associated with complex production processes organised across geographical distances. The important fact about upgrading is that specific design locations and firms not only work their way up the value chain, but that they are able to shift their relative positions within these networks. Of course this process does not abolish the hierarchical organisation of such networks, as it is continuously reproducing it. However, by considering upgrading in the analysis it is possible to grasp the dynamics this process has on the labour process and its organisation.

For the engineering labour process the most important are functional and product upgrading. Through functional upgrading an extended workbench design centre is expanded towards a more integrated form where locally integrated teams are possible. Local integration is lowering the need for standardised interfaces as the labour process is not spanning several time-zones, cultures and languages. Control systems for local integrated engineering teams can also lower standardised reporting and monitoring as day to day personal contacts are enabled. With product upgrading engineering teams are tasked with increasingly complex and new development projects that shift the focus of work from routine tasks towards more contingent tasks of development. As the initial complementary divisions of labour often develop into more complex relations it is important to focus on already relatively developed relationships.

With upgrading the prevalent heuristic model of centre and periphery is becoming at least blurry. Distinct hierarchies between the headquarters and other design centres, based on experience levels, localised management functions and capabilities to influence strategic decisions still prevail. However, they are increasingly superimposed by more complex relations and roles of locations, where e.g. competence centres for specific technologies or products can be shifted to so called low-cost locations. Upgrading leads to shifts in the role a design centre is playing within the design network as well as in the specific work engineers
are conducting in the location. Through upgrading engineers move from receiving detailed work packages to co-determining technical and organisational aspects of their work. How upgrading is taking place as well as how the local labour process organisation is being transformed by upgrading is linked to local characteristics such as the labour market.

3. Engineering work in Eastern Europe

Leadtech is a German chip company developing and manufacturing semiconductor and system solutions focused on automotive, industry and multimarket as well as for chip cards and security applications. Leadtech is one of the leading companies on these markets. The company employs around 26,500 people as of September 30, 2010. Around 5,700 people are employed in its worldwide R&D operations with 50% employed in German R&D centres (Annual Report, 2010). Leadtech’s manufacturing operations are in Austria, China, Germany, Hungary, Indonesia, Malaysia, while its R&D centres are in Austria, China, Germany, India, Italy, Romania, Singapore, Sweden, UK and the US.

Romania has a long history in the electronics and semiconductor industry, with own IC development and wafer manufacturing operations developed already during its socialist era. The remaining capabilities are mostly in educational and research areas, such as the National Institute for R&D in Microtechnologies IMT in Bucharest, which is an internationally renowned organisation. The first multinational IC development companies opened shop at the end of the 1990s in Bucharest. Initially the companies were mostly small start-ups and specialist IC design houses with highly cost-driven business models mainly in markets for analogue and RF products. Many of these operations have changed ownership several times during the last ten years. Today Romania and especially Bucharest is a well established specialist location for IC design hosting several design centres of big multinational semiconductor companies.

Leadtech started its IC development operations in Bucharest in 2005 aiming to tap the talent pool of experienced and still cheap IC engineers. The company was initially able to hire engineers with several years of experience both in IC design as well as international development projects, due to the already developed labour market. In 2010 the Bucharest development centre (BuDC) employed around 200 people, giving it the status of a medium sized development centre in the overall intra-organisational GDN of Leadtech. The BuDC is focusing on automotive applications and chip cards.
3.1. Labour market – competition for talent and stable workforce

The labour market for semiconductor engineers in Bucharest is relatively well developed. A decades long history of the local semiconductor industry has provided both experienced engineers as well as an educational and research infrastructure. These historical resources have been especially important in the initial phases of Bucharest’s integration in the global design networks of the chip industry. The arriving of small specialist companies and start-ups in the late 1990s made use of this talent and developed a quite dynamic local labour market, where companies are competing for talent. The subsequent appearance of bigger semiconductor multinationals has further increased the competition for talent. As software development multinationals have arrived some times earlier and provide also more job opportunities technical universities have increasingly shifted their curricula towards this industry, lowering the numbers of graduate with specialisation in hardware development and aggravating the overall drying up of the local labour market.

Company strategies against this contracting engineering labour market are numerous. The most important focus on the regionalisation of recruitment aiming at engineering talent from adjacent countries like Moldavia. Focused more on a long-term development are cooperative strategies. Leadtech is working together with technical universities on the development of future curricula, as well as providing specialized lectures through its most experienced Romanian engineers. To both bond as well as screen future candidates the company is offering summer and part-time jobs for engineering students. The possibility to develop graduate theses in the company is another strategy.

Although the local labour market is contracting and the competition between companies is rising there is still a relative stability of BuDC’s work force. Most of the engineers working at BuDC are working there since 2005, while new engineers not exhibiting too much interest in changing their employer. Compared to other Eastern European chip development locations the fluctuation rate at BuDC is higher, which is attributable to the developed and competitive local labour market. Compared with other so called low-cost locations in India and China, the fluctuation seems to be almost non existent. However, Bucharest’s competitive local labour market is an important driver for upgrading, as strategic management is pushed to locate increasingly complex products at the design centre to be able to retain engineering talent. All of the interviewed management at BuDC underscored the importance of work force stability for upgrading processes. The build up of experience is important for the enabling of upgrading, as there is a constant capability build up enabling to locate both senior positions.
and more complex projects at the design centre. The stability is also rising planning reliability of development projects extending management interest to locate bigger projects at BuDC.

3.2. IC development – integrated project teams, interfaces and technical influence

The relatively well developed labour market for analogue IC design engineers has allowed Leadtech to ramp-up its design centre in Romania quite fast regarding technical functions. Within only four years the complete development value chain is in place and high profile engineering positions focused on architectural decisions have been established. With the addition of local project as well as program management a second career ladder has been established for the engineers at BuDC. The BuDC is specializing in automotive products complex in regard to process technology as well as environment. The ability to generate stable products for extreme conditions such as the proximity of a hot engine block is a very challenging task. The technical specifics of analogue chip design are drivers of relative high levels of originality, variety and complexity in the work of the particular development engineer. The integrated character of Leadtech’s design centre in Easter Europe allows the IC design engineers to work closely with the local layout engineers based on personal communication. This work organisation lowers processes of standardisation essentially while continuous direct communication allows IC design engineers as well as IC layout engineers a higher level of discretion in their engineering work.

Concept engineers at BuDC are involved in architectural decisions, working on the actual profile of the functionality of a future product. In the initial phase of a development project a feasibility study has to be performed to evaluate if and how customer requirements can be implemented in a profitable way. This involves both technical as well as business considerations that have to be defined in cooperation with the customer, application engineers as well as the sales and marketing department. This phase is characterized by high levels of international communication and cooperation. The feasibility study and the subsequent implementation of the design specifications involve technical and organisational negotiations where engineers from the development team often participate, being able to voice problems and limits and influence the specifications. However, influence of the development team has set limits. The profitability of the product, assessed in the feasibility study is the internally set limit, while the customer and his product request is the externally set limit framing the whole process. Such an open but limited structure of iterative negotiation of the design is opening up the communication process to involved engineers allowing to benefit from their technical insights and experiences. While the integration of engineers in the definition of the
specifications of future projects is rising the technical autonomy it is simultaneously also
driving commitment levels, as engineers strive to develop good solutions informed by
technical and not only economical considerations.

The translation of the feasibility study’s results into design specification is a process
where the concept engineer has relatively high levels of autonomy compared to standard IC
design work as he has both the freedom of tool choice as well as has to make decisions on
how specific functionalities will be implemented.

“In this phase you can work by kind of drawing the blocks but in parallel you
have to do some simulations with some high level languages like SystemC,
Matlab, VerilogA, VHDL, it depends on how comfortable you are feeling with the
language, with this kind of tool. There is not a must to work with Matlab, and
only with Matlab, if you are comfortable with it then you are allowed to use it.
Personally I am using VerilogA, it is something I know very well. […] You are
going down to each block and defining each one. […] Because sometimes the
block has some advantages you can do it in several ways you have various ways
to do this kind of blocks and then if you want something specific you can go and
say use this one, because this is the most suitable for my design.” (Concept
Engineer)

The ideas of the concept engineer are checked for operability and stability and matching
with the customer’s requirements. Often engineers that will subsequently implement the
particular design are integrated into this process to both access their technical experience as
well as align them with technical decisions already at this point.

Design specifications are fixed before design implementation starts and project managers
define the work packages for particular engineers. The phase of design implementation is
generally characterized by low levels of international communication and cooperation, as all
required technical and managerial resources are locally present. However, as customer driven
development projects exhibit a fluidity of specifications that can result in changes of minor
specification. Work requests are then highly driven by customer choice and repeating changes
often lead to frustrations on the side of IC designers. Intensive customer orientation, such as
these change requests are a practice of direct control in the engineering labour process
(Upadhya 2009). Change requests directly affect the work of engineers and disrupt the
workflow of the particular engineer. Intensive customer orientation is shifting the focus of
control from work back towards the particular person. As the ownership of design blocks is
personalized customer driven change requests directly cut through to the particular engineer.
Moreover, change requests not only affect the technical side of design but also make organisational adaptations imperative, which can also lead to overtime.

In both internationalised as well as localised phases of the development cycle interfaces are very important. Standardised formal processes provide only very insufficient interfaces that need to be stabilized. This stabilization is performed by individual engineers through informal initiatives and the build up of subjective skills to cope with the contingencies always present in the development process. Processes that take place within the company and even within the same location are not easily set by formal rules and processes but need to be worked out.

Test engineers are one of the most internationally interfaced positions at BuDC, next to project managers and concept engineers. They are the cross-functional and cross-locational hinge within the product development process of the company. Due to their specific position in the development process with its phased international character test engineers are constantly in the final phase of this process that is exhibiting the highest levels of internationality and cross-functionality. They are one of the most important interfaces both on a spatial as well as functional level.

“We are the link, usually the development team interacts locally, everybody is here, but we need to interact with the development team and everybody from the fab. And then we have marketing and application which are a little bit different.

We are the glue that keeps everything together, more or less.” (Test Engineer)

Test engineers need to develop broad skills that go beyond technical knowledge and experience as one of their major tasks is to be able to work on intra-organisational interfaces. To be able to communicate in a stable way test engineers often travel to the manufacturing operations located in Asia to develop personal relations with their cooperation partners as well as learn about technical characteristics on location. European design locations also often have visitors from Asian manufacturing operations that learn about processes in the standardised design methodology affecting their test operations. Besides such official efforts to develop and stabilize these fundamentally important interfaces test engineers report about independent initiatives.

“It is easier to spend some time on one day to make a pseudo-training, to discuss certain specification, which you find recurring, and then you think how to discuss it, not to make it personal, saying you are stupid, that's not the point. Let's discuss about this, this is delicate, we have to be careful here and here. It took some
discussions but in the end we got the results. I was happy because next time they
did it by themselves.” (Test Engineer)

Such pseudo-trainings are not covered by any formal process in the company. Reliance
only on official interface building procedures would not allow test engineers to work
efficiently and would result in work intensification as glitches and frictions within the
internationally organised process would amount to fundamental problems for the projects’
schedules. Social ingenuity and the associated subjective skills of test engineers are a
necessary capability for such geographically complex processes to function sufficiently
smooth.

The relative high degree of freedom at Leadtech’s Eastern European design location is
facilitating an environment in which engineers perceive their work oftentimes as a playful
activity. Such a positive attitude towards solving technical problems could be impeded by
higher levels of standardisation and formalization. Attempts to introduce broader standardised
control measures stalled mostly due to resistance from engineers. Standardisations based on
technical considerations are mostly well received by the engineering community as they allow
for easier development of increasingly complex systems. However, attempts to implement
standardisations that are mostly based on managerial and organisational rationalization
assumptions, lowering the degree of freedom in engineering work, meet with considerable
opposition. This evidence is much in line with the differentiation between commercial and
engineering logic in rationalization processes developed by Beirne et al. (1998) for software
development. Although both logics often complement each other their relationship is
characterized by a fundamental contradiction. Both logics are based on a different rationality,
where economic pressure and the need to control costs can run counter to technical
requirements and the need to allow for tight process control.

3.3. Work and control – negotiability and trust

The control structures at BuDC are anchored in the system of milestones. The overall
managerial strategy is based on formalized and standardised procedures that define the entire
development process dividing it into milestones. At the end of every milestone predefined
results delivered by every team member are being reviewed for their integrity as well as
quality. However, this highly formalized control structure is not resulting in constant high
levels of control and monitoring. It is rather forming a framework and specific segments
within which relative high levels of autonomy are enabled. The fixed framework of
milestones is brought to life by the negotiability that is a fundamental instrument in the
control of the engineering labour process. The dynamic relation between the complementary milestones and negotiability is forming the basis of the system of layered control. The definition of scheduling and work requests are intricate processes that give engineers possibilities of influence rising both technical and time autonomy.

The entire product development at Leadtech is governed by 11 milestones. This framework is not overly finely grained as it ranges from the initial product idea generation to the stabilized mass-production. Within this standardised and formalized structure more subtle and dialogical processes take place that control and monitor the particular work packages and schedules.

Leadtech has a system of two timelines per project that is used as the framework for communication with the customer, integrating from the onset flexibility into the project’s schedule. The best and shortest scenario, or X-30, has a probability of around 30%, whereas the more relaxed scenario, or X-80, has a probability of 80% of accomplishment in the set timeframe. These two scenarios are also used for internal communication with the development team and every team member is advised to try to be on X-30. However, as contingencies are always present achieving X-30 seems not realistic, and as one project manager states: “Ideally if you are a good planner you should be somewhere in the middle […]” of X-30 and X-80. This procedure to define and communicate both externally and internally the probability of project completion sets up a framework for relative autonomy. The flexibility communicated by this system, that is translating into a relatively high level of time and work autonomy, is reversing itself as it has the possibility to perform more efficient and faster inscribed in its very own semantics.

The definition of the future project’s schedule is a detailed and highly formalized process, where ownership relations between particular engineers and design blocks as well as schedule commitments are iteratively established. The result of this negotiation process is always limited by the schedule constrains pre-defined by the customer. This negotiability of project schedules is the focal point of the layered system that governs the labour process of engineers. Although engineers can voice their reservations within these negotiations the final decision is taken by management and the customer. Besides general time estimation negotiability, engineers are able to voice estimation uncertainty, especially when they are designing with very new blocks.

“Sometimes you can get a very, very new block and you can have a problem with this kind of estimation, due to the fact that you don’t know what to expect. And then you let your gate open: I don’t know if I will do it in 2 months, but please be
preparing to help me yourself or give me a person. It can be negotiated. […] You have to start to cry in the beginning: I cannot do this in 2 months and maybe the team leader, or resource manager will allocate another person, or a better one, or a person to help you, but you have to start crying at the beginning.” (Concept Engineer)

The schedule is negotiable depending on the specific technical complexity as well as the subjective ability to see and voice future problems. Negotiation and organisation skills are fundamental in this process for engineers. Only if an engineer is able to establish his position right at the beginning of the process will he be able to accomplish his work without excessive pressure and resulting stress.

While benefitting from the engineers’ organisational knowledge that allows for a more realistic project planning this dialogical albeit hierarchical decision process prevents uneconomical designs, that would cater more for the technical ingenuity than fast project completion. However, the integration of engineers in the definition of schedules establishes major pillars of relative autonomy as both autonomy is upheld and the commitment through such an open culture is produced. But as the definition of project schedule is still negotiated in a hierarchically structured system project schedules are tight. There is a further component of direct control in this situation as the amount of planned in contingencies defines the future intensity of work as well as time autonomy for the engineers.

The negotiability of schedules is extending time autonomy beyond the ability of a particular engineer to relatively autonomously organise his tasks. The ability to influence the schedule framework itself is establishing a time autonomy of second order, important for the legitimization of the labour process organisation and work intensification. It raises responsibility and expands ownership from work packages towards the entire project. In arduous times of work intensification and overtime a discursive element already exists that potentially averts the sole responsibility for such a situation from management. As the schedule is planned based on estimations and the system of two timelines allows for some flexibility overtime is neither regular nor is it being encouraged by management. However, milestones can drive overtime when specific deliverables have to be completed. The autonomy that is established by the milestone systems reverses into strict and often direct control when a specific milestone is due. However, no direct sanctions are reported if milestones cannot be met.

Time autonomy is controlled by the hierarchies of job positions. The amount of overtime is related to the position of a particular engineer within the product development process and
seems to be endemic in functions that are responsible for the final part of chip design, i.e. physical design or layout.

“Unfortunately a layouter has some very easy periods, when the design is starting the layouter has nothing to do, because you are waiting for the first schematics to be finished. And in the last weeks you have a very, very hard time. Overtime, nights here in the office. This happens in every project.” (Analogue Layout Engineer)

Despite the flexibility within the system of two timelines the project’s schedule defines in a quite strict way the moment when the so called tape-out, i.e. the delivery of data to the manufacturing operations, has to happen. IC design engineers know that they have a time buffer located outside their task, which they seem to use to absorb contingency related scheduling problems within their own work. The organisation of the development process in a sequential way establishes a hierarchy of time autonomy between the various engineering functions. In such a system time flexibility is not a characteristic of a high level of autonomy as it is not connected to a situation of time autonomy. Layout engineers are forced into the situation of time flexibility and the associated regular overtime by the specific organisation of the labour process. Some design engineers perceive this situation also as problematic. However, as most of the contingencies within the design process are driven by customer change requests design engineers are only partly able to mitigate this situation. As the negotiability of schedules is extended towards the implementation of the schedule itself it is establishing and reproducing hierarchies of time autonomy within the system of sequential work organisation. This leads to the elimination of almost all time autonomy from engineers that have to perform the last steps in the sequentially organised development process. Here the power structure within the labour process and between various groups of employees becomes visible (Friedman 1977). Hierarchies between workers are related to their centrality of tasks as well as the value added provided by their work.

To be able to monitor the labour process management is using both software tools as well as a finely meshed system of meetings and reports. The most fundamental instrument of control on this level is the development of trust between management and engineers. Trust is necessary for both automated instruments of control as well as subtle forms of dialogical control. Although trust has been developed at BuDC and control is focused more on work than on people, engineers need to fill out time sheet, which are an instrument of direct control focusing on people. This situation is a depiction of the recurring contradictions in the labour process at BuDC between autonomy and control, that are on the one hand essential for a
system layered control, on the other hand do often result in frictions. Besides standard tools for project resource and schedule planning such as MSprojects as well as Excel Leadtech has an internal tool, where not only milestones but also more detailed information on costs and the overall progress of the project is being gathered and processed. All automated tools rely on data put in by engineers.

In the initial phase of the design centre weekly reports from every engineer were mandatory, where engineers had to report on every day of the work in detail. This lead to resistance from particular engineers against this finely grained control.

“Of course we had a lot of discussions about this. I did not want to fill in another document. I am going crazy, I need to do my stuff, I am employed as engineer and not to fill out documents. Let’s find a way the number of documents. Let’s do it on a basis that is not interfering too much, not too many meetings for discussions.”

(Test Engineer)

The result of this resistance was that the weekly reporting was cut down to the production of a very synthetic report consisting of one Powerpoint slide, where engineers provide an overview of the progress of last week. Although the engineers were able to fight back impeding control depth the reporting system is still one of the main and most intrusive moments of managerial control strategies, as the compliance to its requirements is linked to the yearly evaluation of every engineer that is influencing future career possibilities. The framework of relative autonomy is guaranteed at least in parts by a system of evaluation and rewards on a more general level, which is nevertheless exhibiting characteristics of direct control. The observing of certain standardised organisational rules is guarded by rewards and punishment.

More important than these broad formal management tools are dialogical forms of control such as various and regular meetings. Here the focus is on the task and its completion and not on the time that has been worked by every engineer and formal reporting. During weekly team meetings engineers report about progress and problems allowing the project manager to have a constant overview of the project’s status. Discussing a particular problem within the team enables the project manager to understand and assess it in the context of the whole development project. However, these weekly meetings are mostly focused on organisational issues, as technical problems can be discussed directly between the particular specialists and the project manager. The project manager outlines the results of the weekly meeting in a report delivered to his superior. Day to day communication within the project team as well as with the project manager is one of the most important control tools for
management. This personal and direct communication establishes the necessary levels of trust on both sides that allow for the required level of autonomy.

The daily communication with the project leader establishes a closely meshed system of personal monitoring. The role of the project leader epitomizes the dynamic of control within a changing international division of labour. Local project leaders are a major step in the functional upgrading of design centres, as managerial responsibilities are localised. Remote project management requires high levels of formalized monitoring and control with openly direct control strategies based on continuous reporting. Local project management allows for a much more intimate monitoring while simultaneously lowering the required amount of reporting of every single engineer. The possibility to talk daily to every project member gives the local project manager the ability to establish a system of personal monitoring and catering for the needs of engineers. This very personal control allows for the development of higher level of commitment. The results of this daily monitoring are routinely aggregated and forwarded to higher management, however the particular engineer is not anymore caught up in this process of data generation. With this personal control the project manager acts as a suspension between management and engineers. Locally integrated teams are the basis for the relatively open control structures based on dialogue and trust. The spatial proximity allows to develop informal communication and eases up problem solving. For management the oversight over a locally integrated team is much less time intensive than for highly internationalised teams. The requirements for automated and formalized control tools that can drive resistance from engineers who do not want to be bothered with administrative tasks are lowered.

4. The internationalised engineering labour process in semiconductors

The overall identifiable managerial strategies at Leadtech’s Romanian design centre tend towards responsible autonomy, which is a general characteristic of the engineering labour process and a dynamic found also for knowledge intensive work (Warhurst/Thompson 2006). However, this is an interesting observation for peripheral locations within the internationalising semiconductor industry, as it is a tangible evidence for shift of the internationalisation dynamics itself. Moving away from structures of complementary international division of labour a new phase of internationalisation has already begun. The still existent hierarchies cannot anymore be read off from the specific geographical location of a particular operation within a global design network. Now a more focused view is necessary.
to determine the technical and organisational capabilities as well as the organisation of the labour process to be able to understand what kind of positions a particular design centre is taking in the hierarchical global design network. Characteristics of responsible autonomy are prevalent, yet strategies of direct control exist and are undergirding and at some points even driving management practices specific for autonomous work. The dialectical relation between various layers of control is enabling an organisation of work in an international context where management can assert control over the labour process while leaving enough room for engineers to innovate. Work organisation and control are developing within the process of upgrading and specific local characteristics, in particular a highly stable workforce and limits on the local labour markets.

The most important insight from the case study is the conclusion that functional upgrading of design centres within a global design network and the development of integrated teams are fundamental steps to develop an effective system of layers of control that allows for an efficient production. Such an organisation of the international division of labour allows to reduce interfaces and the requirement of their standardisation as the most important technical functions are co-located. Lower levels of interface standardisation can push autonomy in the labour process allowing to access the engineering creativity and facilitate motivation through more complex projects and technical responsibility. The high management cost of implementing highly standardised interfaces are lowered while engineers are not required to invest too much time on the necessary development of stabilising informal relations. Simultaneously integrated development centres allow for direct personal control measures that are necessary to bolster the high autonomy levels and are perceived as less intrusive and coercive. While functional upgrading develops the preconditions for an effective control system that tends towards responsible autonomy, processes of product upgrading are necessary to establish essential technical prerequisites for a good functioning of this system. Satisfying the intrinsic interest of engineers in complex technical problems and solutions is a fundamental factor in the establishment of consent in the engineering labour process. Integrated engineering teams that focus only on derivative projects, or projects of low complexity will develop resistance practices, that will disable an effective development process. With a dynamic local labour market changing employers is an important resistance practice. This strategy is a way for the individual engineer to develop his career through experience accumulation and broadening of technical specialisation. To evade such a situation and establish a stable and working labour process functional upgrading has to be coupled with product upgrading.
However, the development of locally integrated development teams is not a mechanic process of functional adaptation. Local characteristics play a decisive role in how such an upgrading can occur. Regulatory frameworks provide the required overall stability and universities the educational and research related resources. The features of the local labour market as well as labour force are most important in the process of adapting global internationalisation strategies of companies. The stability of the labour force coupled with the relatively competitive local labour market provide a very localised framework that is producing pressures on the strategic focus of BuDCs development. The accumulated experience is translating into localised technical and organisational capabilities that can be put to use by the company. Simultaneously, these local characteristics also drive the specific labour process organisation that we described above. The organisation of the entire development process though an integration of local engineers as experts and not as receivers of only detailed work instructions fundamentally affects the organisation of the labour process. This shift in the way how engineers are integrated into the overall international division of labour, the move from passive to active participant in the technical and organisational aspects of work, is fundamentally connected to processes of upgrading in peripheral locations of Global Design Networks.

The example of the concept engineer as a central role in the development process at the intersection between engineering and management is important in regard to dynamics of the international division of labour. Locating such a central role at a peripheral location such as the BuDC indicates how hierarchies are shifting in the organisation of engineering work. This has fundamental implication at least for parts of the local labour process. As the concept engineer has very high levels of autonomy in his work it becomes clear, that control levels are not solely determined by the geographic location of a specific position along the centre periphery divide. The centrality of the position itself combined with local labour market characteristics are fundamental drivers of the organisation of this specific labour process.

Internationalisation and the processes of upgrading have effects on the skill sets required to be able to work as an engineer in a global design network. The described case of the test engineer depicts nicely how skills that are rooted in subjective capabilities are increasingly important to stabilize complex project related interfaces that integrate territorially distant co-workers. The increased responsible autonomy linked to upgrading within global design networks is also driving requirements for more subjective aspects of the engineers’ skill sets. The negotiability of schedules is tending towards a more autonomous labour process.
However, how an engineer is able to position himself within this process depends on his highly individual ability to negotiate.

Processes of upgrading facilitate both more complex systems of control and labour process organisation as well as dynamics in engineering work that drive technical complexity perceived as positive by engineers. Yet, it is not definite which process is triggering the dynamics, as functional upgrading can be the necessary solution for problems of control, commitment and motivation. The causal correlation is not determinable from the data in the case studies. However, as we see throughout the entire study the effects of a dialectical process between local and global a clear answer to this question seems not possible. The important insight is that processes of functional upgrading are not solely driven by strategic decisions of cost cutting and customer or market proximity. The capitalistic imperative (Thompson 1983) to organise the labour process efficiently and profitably by asserting control over it through appropriate managerial strategies is an important driver in processes of upgrading. It is important to analyse the specific global design network, the position of a particular design centre within this network as well as its local institutional framing. This analysis then can serve to understand the specific characteristics of a particular local labour process.

5. References


Rainie, A., S. McGrath-Champ & A. Herod (2010), Making Space for


