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HÖGSKOLAN HALMSTAD

# GUIDELINES FOR COUPLING OF THE BUILDING FACILITIES TO THE EXTERNAL AND INTERNAL DEMANDS GENERATED BY THE SOCIETY.

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ABSTRACT
This paper summarises long-term experiences from research and industrial implementations of research results within the Swedish automotive industry concerning unorthodox assembly system designs. The article also refers to recent experiences concerning participating in projection of university buildings. Thereby the authors form a base for arguing for, as well as illustrating, some general conclusions regarding organisation of the transition of research results and industrial experiences as well as articulating guidelines for coupling of the building facilities to the external and internal demands generated by the society. This is due to, according to the authors' experiences that the building facilities constitute a vital interface between the academy and the industry.

## 1 BACKGROUND

Today changes in the industry, i.e. outside the university, are accelerating, at a pace far more rapid than within the academy. Thus is, according to the authors' experiences, an action-oriented research approach a necessity within some scientific disciplines treating certain problem areas. This especially concerns broader scientific disciplines represented by newly established applied sciences and various phenomena connected to industrial and commercial matters. It is, in the light of the authors' experiences, not likely that other means apart from a simultaneous co-operation between practitioners and researchers will generate knowledge applicable for the society, e.g. knowledge implemented within an industrial context generating profits, improving the human qualities of work, etc. This depends on that the industry is under a process of change at a speed, which in most cases exceeds the pace of the individual researcher who, e.g., strives for personal academic merits through academic publications.

This rapid process of change thus comprises a different time perspective than is common within the academy. The industrial time perspective on this transition is in some cases a matter of years or less, while the scientific time perspective for developing and establishing "new knowledge" within the academy is a matter of decades, especially from the individual's point of view.

On the other hand, the larger industries are, from the individual scientist's perspective, prone to tackle extensive tasks by organising the work as projects. Usually the knowledge gained in these projects is either (1) lost after the projects are dissolved or (2) inherited by individuals not always appointed formally responsible for this transfer of knowledge. Note that the formal organisation within industry is generally not coherent with the informal structures, i.e. appointed persons are not automatically individual entrepreneurs, something which to some extent is the case among the senior researchers. Nevertheless, the responsibilities and mechanisms of succession of established knowledge or insights gained are by no means clear, neither within the academy nor within the industry. To be frank – these matters are vital – but the mechanisms are usually not clear enough. Apparently some sort of transfer mechanism is present in both cases but this is in no way explicit. However, the transition of research results and industrial experiences dependent on the way of organising (see section 2) which in turn may be hindered or promoted by various preconditions of the academy. One such critical precondition is the building facilities. This precondition is vital today for several reasons. Some of these reasons are discussed below while others are omitted.

To summarise, this article will argue for specific principles to organise the transition of research results and also stipulate some guidelines for coupling of the building facilities to the external and internal demands generated by the society. These insights are based on the author's long-term experiences when implementing research results in the automotive industry as well as recent experiences concerning participating in projection of university buildings. The article will also underline the sometimes important issue of co-operation between practitioners and researchers which in some cases is a necessity and could in fact be organised constructively while, on the other hand, the universities' way of organising their building projects calls for some criticism.

## 2 THE TRANSITION OF RESEARCH RESULTS BETWEEN ACADEMY AND SOCIETY.

Action-oriented research approaches that are integrated with the industry, and thus maybe also into the society, are to be found in many problem areas represented by various scientific disciplines. However, academic publications are not frequent. The research results reported are likely to be based on a sometimes vague theoretical foundation not in all respects accepted by all scientists.

This especially concerns those scientists belonging to, or arguing from, a strict natural science point of view, which is due to, among other things, that an established and grounded overview of the scientific status is missing. Thus action-oriented research approaches are not fully recognised by disciplines of the academy. For example, to circumvent this dilemma some research foundations have coined the term "research and development work" since this term legitimises phenomena which may otherwise appear to be contradictory, by amalgamating specific problem areas with financial opportunities. In turn, these opportunities may, or may not, generate scientifically approved research results possible to implement on an industrial or commercial scale.

Example 1:

- The governmental financing of "research and development work" is in most cases looked upon as a preliminary support, a preparation, for a later commercialisation, i.e. assuming to predate various forms of future product development activities. This traditional sequential way of organising this transition is usually time-consuming, leading to maybe decades of work until the research results are integrated within the society. However, a less time-consuming procedure is to organise the transition parallel as an iterative and combinatorial process. That implies for example supporting a product development work with a relatively modest contribution of research.

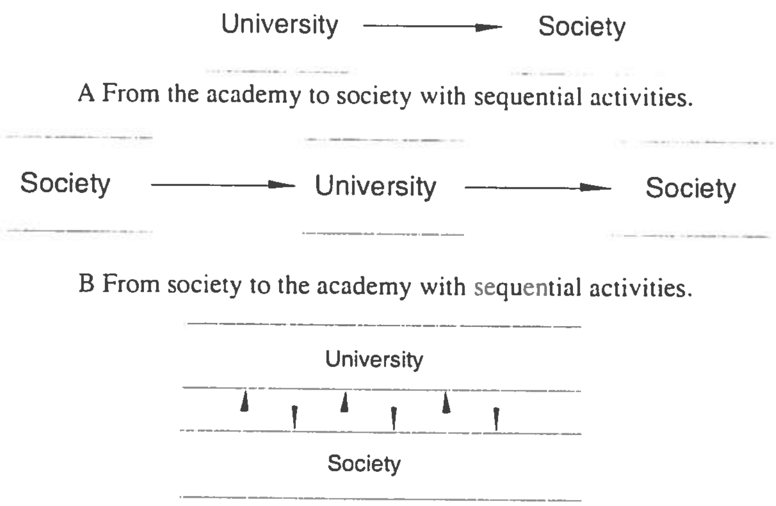
One such example involved a Swedish truck manufacturer, who in 1995 was submitted an offer by an industrial design consultant concerning the development of an improved cabin suited for forklift trucks. In this case the research foundations (the Swedish Work Environment Found) subsidised a minor sum to the industrial design consultant in order to integrate ergonomic aspects into the original design. In short, by combining quite elementary knowledge about ergonomics subsidised by the research foundation, with some extra initial resources aimed at commercial issues ("seed money"), it proved possible for the industrial design consultant to approach the truck manufacturer with a more "advanced" tender. Due to the funding the consultant went ahead and made sketches of the improved cabin design which were first evaluated by the consultant from an aesthetic point of view. Thereafter a brief ergonomic analysis, carried out in three weeks and financed by governmental resources, illuminated the work situation of truck operators with the help from a senior researcher (Department of Biomechanics at Hälsohögskolan i Jönköping).

All this resulted in a constructive discussion between the consultant and representatives from the truck manufacturer's marketing-, research- and development- and manufacturing engineering departments. In turn, this discussion led to defining to what extent the original cabin design ought to be modified in order to suit the forklift operators' preferences and needs. In fact, this was a compromise since not all possible ergonomic features had to be incorporated in the first generation of prototypes. Only those features possible to implement on the market required attention, i.e. to clarify the definitive improvements in relation to competing truck manufacturers' products.

The investment from the research foundations was about 10% of the total investment of truck manufacturer's product development activities; the rest was paid by the truck company while the cost for the initial "research and development work" (i.e. the ergonomic analysis) was about 5%. The number of muck-ups and prototypes required to reach the final product (i.e. the commercial design) was about four. These muck-ups and prototypes were needed in order to consider aspects like acceptance from customers, ease of manufacturing, cost estimations and logistics. However, the convincing argument for the truck customer proved to be a decreased level of sick leave due to enhanced ergonomics combined with an improved performance. These features emanated from better sight, less tiring working positions and improved manoeuvrability.

From the researcher's point of view, the merits of this combinatorial funding of "research and development work" was in form of a realistic case comprising commercial implementations during a short time window. It was thereby for example possible to evaluate the cabins' features in field studies after some years. On the other hand, the truck manufacturer was able to generate profits based on a deeper involvement in the task of designing more user-friendly truck cabins.

Example 1 illuminates that "research and development work" in some cases may be organised parallel as an iterative and combinatorial process, comprising a reciprocal action between practitioners and researchers implying various kinds of joint-venture coalitions.




C Iterative and combinatorial process with parallel activities.

Figure 1, Three principle ways of organising the way of transition research results and industrial experiences between academy and society.

The transition of research results into knowledge applicable for the society may be organised in various ways (see figure 1). The most general assumption of how this process is organised is either that the academy delivers research results for implementation in the society (A) or reacts upon a request from the society (B). It may be argued that the latter process would be more suitable if it is organised as an iterative process by numerous loops between the society and the academy. However, it will still be time-consuming since the time windows are sequential.

Example 1 underlines that an iterative and combinatorial process, where the research and development work is organised in parallel, might in some cases be a faster way (C). A prerequisite, however, is that the researcher strives for an extended time window. Last, but not least, there must exist some sort of overlap between problem areas treated by the practitioners and researchers or alternatively, that the joint-venture coalition comprises development or refinement of scientific research methodologies, applicable to other problem areas. Otherwise incentives for co-operation will not be evident.

Hence, "research and development work" connected to, or integrated into, the industries' normal life will affect the "curious scientist' role. Apart from that, his or her paradigmatic discourse which is related to the mother-discipline, might cause some personal mental exertion, since also established research methodologies often need to be questioned if industrial implementations is the purpose. This depends on that e.g. the methodologies must be approved by company representatives and maybe unions as well as accepted by the personnel involved. The researcher will thereby gain a new role since it is vital for him or her to recognise and accept the needs to organise various constructive long-term alliances between the academy and the industry, based on personal relationships rather than arrangements based solely on discussions on management level.

These specific circumstances have in some selected cases been recognised by research foundations and also supported by industrial initiatives. Thus have, in some cases, individual researchers been legitimised by the industry to successively gain freedom to advance beyond the front line of established knowledge. Some such joint-venture coalitions are briefly hinted at below (see example 2). In the successful cases this has in fact been a matter of long-term personal contacts and a matter of unique circumstances which might never be repeated.

## 3 ONE OF THE AUTHOR'S EXPERIENCES FROM WORK WITHIN THE SWEDISH AUTOMOTIVE INDUSTRY

The industrial implementation of research results referred to in this article is a design procedure that has been refined and used by the author in five case studies involving long-term co-operation between industry and university.[1] In most of these cases it has been a matter of design of assembly systems. These assembly systems comprised parallel product flow, long cycle time assembly systems, which have more degrees of freedom than the traditional serial product flow assembly system (i.e. the assembly line). Thus the design procedure is more demanding and requires an elaborate theoretical foundation, a foundation not yet fully crystallised and internationally communicated among practitioners as well as researchers.

In short, the work hypothesis for design of parallel product flow, long cycle time assembly systems, demands for what is called a structural congruence between (1) operators' perception of the assembly work, (2) the materials display at the work station, and (3) the information at the work station in form of e.g. work instructions and product variants codification. This will in turn require an assembly-oriented product structure, i.e. a product structure that describes the product and its components from an assembly point of view. This is in contrast to the existing, traditional design-oriented product structure used within the Swedish automotive industry based on the so-called function group register. The design procedure comprises restructuring of several subsystems as well as the questioning of traditional knowledge and practice within the automotive industry. For a more detailed explanation of theoretical and practical frames of references, which is not possible to include in this chapter, see e.g. Medbo (1999), Engström, Jonsson and Medbo (2000) or Engström and Medbo (2000).

The introduction of unorthodox assembly systems called for a reformed product perception by operators and engineers. This proved possible to achieve by reforming the product information which was already available in the traditional design-oriented product structure, complemented also by the existing product and manufacturing process data into an assembly-oriented product structure. This reformation is an essential requirement since it facilitates the design procedure and promotes the introduction of e.g. non-traditional materials feeding techniques (i.e. it is necessary for the function of the new assembly system to communicate with the traditional design-oriented product structure).

Example 2:

- Disassembly of products as is illustrated in figure 1, is one of the vital steps in the design procedure referred to. Disassembled products were used for design of several assembly systems and for restructuring of an information system respectively. To the left there is a photograph of a disassembled automobile (Volvo 800-model) from the design procedure of the Autonova plant in 1995 and to the right a photograph of a diesel engine, disassembled at the Scania engine assembly plant in 1998. In principle, these disassemblies constituted an additional development of analyses done for the design procedure of the Volvo Uddevalla plant more than ten years earlier. The removed components were for example organised according to so-called modules of work (i.e. a work content related to work positions along the product where the total assembly work on e.g. an automobile will comprise 20 – 35 such modules) in the Autonova case. In the Scania case, on the other hand, the components were organised according to the individual operators' work at specific work stations along the existing assembly. In both cases the components were separated by means of wooden laths. It ought to be noted, as is evident in the photograph from the work at Autonova, that specific labels were fixed to each component representing various product variants and complemented by small paper cards guiding the disassembly. These cards were positioned on the tables next to the removed components and comprised an illustration of the assembly work and the appropriate product variant codification etc.

In the Volvo Uddevalla case, which like the Autonova and Scania experiences was a matter of long-term engagement for the researcher, a number of parallel activities were going on during a long period of time (4 – 5 years). In fact, three interacting poles were forming a network which successively was crystallising an iterative and combinatorial "research and development" process.

These actors were constituted by (1) the project organisation managed by Volvo, initiated in

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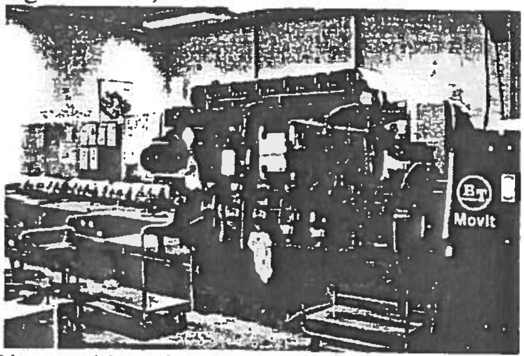
[1] These five cases are (1) The Volvo Uddevalla plant 1984 – 93, (2) The Volvo Torslanda plant 1989 – 89, (3) The Volvo Truck plant 1989 – 90, (4) The Autonova plant 1995 – 97 and (5) The Scania assembly line 1998 – 99. The design procedure was initiated and used for the Volvo Uddevalla plant design and was revised in the redesign of the Volvo Torslanda main plant, a redesign which was never implemented, and for the Volvo truck plant in Tuve, as well as for the Autonova plant. All these four cases used or use parallel product flow, long cycle time assembly systems. The last case is the reopening of the Volvo Uddevalla plant, operating as a joint venture between Volvo and Tom Walkinshaw Racing (TWR), denoted Autonova. This company manufactures exclusive coupés and convertibles for Volvo. Finally, restructuring of the information system at the Scania diesel engine assembly at the main Södertälje plant utilises the same design procedure, but with the aim to improve the quality of data supplied to the operators at the work stations along the existing assembly line.

early 1985 and situated in Gothenburg; 2) the experimental workshop that started in the summer of 1985, also situated in Gothenburg within reach of the project organisation; and (3) the training work shop which was situated in Uddevalla. The training workshop was started in 1986 and was responsible for the training and learning of newly employed operators as well as for the evaluation of various assembly system designs (se Ellegård 1989).

Disassembly at Autonova in 1995 for design procedure of the assembly system.




Disassembly at Scania in 1998 for restructuring of the information system.

Figure 2. Disassembly of products performed during long-term joint-venture coalitions between practitioners and researchers. This work required extensive space, i.e. premises not available within the university, but also data communication with the companies' various information systems and sufficient security (sometimes dealing with new models, expensive components and tools, etc.).[2]

Though the design procedure briefly described above was time-consuming, it resulted in the building-up of knowledge, as well as served as a method to formalise practitioners' knowledge. An example of this was having Volvo expertise continuously checking, and in some cases participating, in the work performed by the researchers by, e.g., cross-reading constructed alphabetical registers and "dictionaries" describing product functions, explaining anachronisms, calling for specific documents required for the running-in of the plant in the form of assembly instructions and product variant specifications, etc.

## 4 SOME ORGANISATIONAL CONSIDERATIONS WITHIN THE ACADEMY WORTH NOTICING WHEN ORGANISING ALONG THE SKETCHED LINES

According to one of the author's experiences, it must be emphasised that "research and development work" ought to utilise the university, in form of the mother-discipline, as the sole organisational base. Personal consulting or utilisation of separate research institutes has to be avoided, as this might lead to impoverishment of long-term development of knowledge within university. The mechanism to aim for is to create a coherent work group, which in itself guarantees a long-term accumulation of knowledge, while the close industrial co-operation will create a high research pace as well as guarantee practical relevance. Not being aware of the dangers of excessive "commercialisation" is especially critical in applied research fields where complementary financing in the form of e.g. short-term consulting projects is relatively easy to obtain, usually at the expense of the parent organisation.

Concerning the development of unique research methods, it should be noted that it is a matter of gaining, both a personal and collective, confidence between complementary scientific disciplines through co-operation between senior and junior researchers. This is due to, among other things, that the work load and work opportunities thus are likely to accelerate. Lacking such personal and collective confidence will in fact only eliminate or restrict these features. These effects will increase substantially if senior research competencies are based on earlier long-term personal co-operation.

In this respect it has for some of the authors proved to be viable to, in a long-term perspective, focus on development of unique research methods. By developing these research methods as an intra-research group member activity, we have also created internal co-operation between members, thus

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[2] Since such premises were not available within the university one of the authors, with financing from Volvo, rented premises at the closed down shipyard at Eriksberg in Gothenburg, used as the experiment workshop mentioned in example 2 which in total embraced 500 square metres during 1985 – 1993. This shop was later moved to another location at Ringön during 1994 – 95. In these premises there were 4 – 7 persons, some of them employed by Volvo. The premises at Chalmers University of Technology allocated in 1995 – 1999 were closed down due to internal conflicts (see figure 4). New laboratories will be finished in February 2001, while the general question of an extremely high rent for the university premises is still not solved in a constructive way.

avoiding internal competition with regard to empirical data and financing, as well as speeded up the research and development processes in themselves. One example of such methods is the design procedure briefly described above or a computer-synchronised video equipment (Engström and Medbo 1996). This equipment has been used and developed during the last eight years within various research projects for grasping the time consumption in for example materials handling and assembly work but also lately for coupling the time consumption to physical exposure by means of technical recordings (Forsman et al. 2000).

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Long-term joint-venture coalitions along the lines sketched above, between practitioners and researchers, usually require participation of the most experienced senior researchers, and might also prove to result in intermittent academic publication; the latter since in some cases, industrial partners are not always keen to allow publication during an ongoing co-operation. On the other hand, such a co-operation might, as has been the case for some of the authors, provide primary data not accessible to other researchers. All this results in intensive periods of academic publication intersected by long periods of various industrial engagements.

Another aspect of this way of organising the research work is that it might result in extensive unpublished material not fully prospected academically. This is in fact the case for one of the authors who has accumulated extensive empirical reference data derived from a number of projects which is stored in an archive at the university, an archive whose utilisation is contracted between the university and the respective industries.[3]

Generally speaking, the sketched way of organising the research work may on one hand make it difficult to identify exactly which activity ought to be defined as belonging to a specific source of financing. On the other hand, this will correctly organised vitalise a number complementary activities, i.e. various opportunities leading to e.g. complementary financing which for various reasons is not possible to prospect within the ordinary resource frames of the university.

The complementary financing will be generated if there is financing available that allows work within a specific problem area valid for long-term development of knowledge. Thus complementary financing, from e.g. the industrial co-operation, will function in a subordinate role. It is therefore possible to select the most interesting aspects defined by the complementary financing. Such resources constitute a potential for investments in machine equipment, computer support and development work, etc. as well as building up long-term co-operation with national and international researchers. The access to an experimental environment in form of e.g. laboratories filled with various examples of research results and corresponding materials and equipment has, in one of the authors case, proved valuable in order to interest new industrial partners since the hardware has proved to be quite convincing when it comes to the practical aspects of life.

However, the changed administrative preconditions during the last two years at the university have affected the research work and obstructed the possibilities to carry this practical research approach further. In fact, the escalating indirect costs added to the researchers' salaries, and costs for material, are not fully covered by the government research foundation's financing, which calls for both some intriguing bookkeeping as well as hard work by researchers; these are facts which successively will be difficult to accept. This, in turn, leads to extremely uncertain preconditions for carrying out research work along the lines advocated in this article. Recently, this particularly concerned the hire of premises within the university, which for the moment calls for financing not readily available and certainly not treated in an especially constructive manner by the responsible persons.

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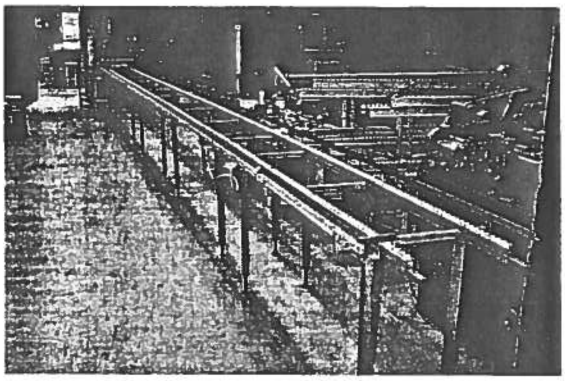
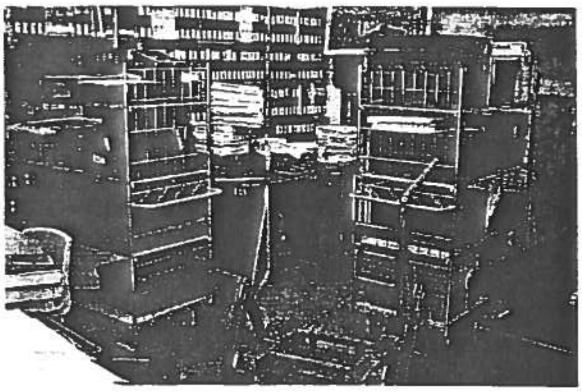
[3] In for example the Uddevalla documentation process, the archive primarily contains e.g. the following registered materials: documents found at the plant (including consultant reports, different kinds of protocols, education materials, internal reports, original performance files, production engineering documents, time-and-motion studies, etc., schematic analyses of flow patterns, buffer volumes, video recordings of assembly and materials handling work, video-recorded structured interviews with the operators, etc.). Some of the documentation was collected and developed by Volvo employees during the closing-down period at the request of the managers. The material from the Kalmar plant is even more extensive. It includes the general archive administered by the mail function, an archive used by the public relation department, the archives of the four managers of the plant, an old archive of drawings of the building facilities, video recordings performed during the closing-down period, interviews with vital persons performed during the documentation process, etc.



The prototype kitting equipment developed for the automotive industry.



The Volvo Uddevalla and Kalmar archives.

Figure 3. Earlier one of the author's experimental laboratory at Chalmers University of Technology comprised e.g. a prototype kitting equipment developed for the automotive industry (to the left). This equipment was used for prototyping the materials feeding technique for e.g. the Volvo KSO and the Autonova plants. The equipment consists of various generations of roller conveyors with light-emitting diodes in order to simulate non-traditional picking information, i.e. picker-to-light (the operator has both hands free during the picking operation).[4] The Volvo Uddevalla and Kalmar archives (to the right). Note the mobile tables used for structuring of documents during the research work. These tables have, in fact, been designed as collapsible in order to move them to industrial premises for field work.

## 5 SOME GENERAL GUIDELINES DEFINED DUE TO INDUSTRIAL CO-OPERATION INCLUDING SOME SPECIFIC GUIDELINES FOR COUPLING OF THE BUILDING FACILITIES TO THE EXTERNAL AND INTERNAL DEMANDS GENERATED BY THE SOCIETY

Firstly, stating some general guidelines for bridging some of the restrictions towards constructive long-term alliances of co-operation between practitioners and researchers based on all of the authors' experiences:

1 It is recommended that a long-term coalition recognises the scientists' need for academic merits by publication, since this might in some cases be "a stumbling block" due to the companies' policies, commercial secrets, etc. One of the authors has dealt with this probable barrier by constructing written agreements stating that the industrial partners are allowed to scrutinise publications dealing with research results from the co-operations. Such an agreement also comprised the understanding that no company data concerning costs and products is to be published. If this is the case the data must be distorted to conceal the source or normalised so absolute costs are not accounted for.

2 An important matter for the scientist is "to secure data", i.e. to be allowed to save various types of materials and data to prove that he or she has been involved in or is responsible for specific "research and development work". This data may later be accounted for in the case of questioning the source during examination for higher academic ranks. The creation of some sort of internal archive, preferably located at the university, is thus recommended.

3 Agreement on manufacturing of dual prototypes or dual experimental test equipment, i.e. development of one hardware for the use of an industrial partner, and the duplicate aimed for use at e.g. the researcher's laboratory. This procedure may in some cases be complemented by an agreement for the researcher's part to, in an appropriate way, publish data from experiments carried through by the industrial partner. This data may later be exploited for academic publications. Note also, that in some cases the co-operation might generate a vast amount of data. In such a case this data might be utilised for establishing new relations between

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[4] There are two principally different kitting methods, (1) conventional picker-to-part respectively (2) part-to-picker. The last method has proved to have an efficiency potential. In the figure above is the first generation of prototype kitting equipment used in the Autonova plant. The budgeted materials handling time for kitting of materials in the Uddevalla plant materials workshops was 7.67 hours including small materials kitting in plastic bags of 0.76 hours. These figures have, according to our own as well as Autonova's calculations, the potential to be reduced extensively corresponding to a materials handling of approximately half this time.

researchers. It might prove valuable for one scientist to be generous, sharing or rendering other researchers' unique data, just in order to establish help from complementary scientific disciplines.

Secondly, without getting into details of these statements, as is the purpose of this a paper, they lead to some insights concerning the appropriate building facilities which is a vital interface between the academy and the industry. The guidelines crystallised – based on the author's research and recent acquaintance with the university's way of managing their building facilities – are:

1 There is a need for neutral experimental environments where practitioners and researchers can encounter one another to tread selected problem areas in a concrete way. Such environments ought to be fully equipped with e.g. word processors and computers, copy machines, telefax, internet connections, etc., in order to readily be able to communicate with the outside world. Thus, appropriate data support, including direct links into the industrial partner's own information systems, is sometimes a necessity as well, of which the latter option might cause some anxiety due to security reasons.

2 These experimental environments must be suited for their purposes and comprise the suitable tools and various materials, available for fast construction of prototypes or muck-ups. Access to various sorts of selected paper charts, wooden laths, junk materials, etc., is preferable.

3 For some specific purposes, entrance to the laboratories by a loading bridge or by heavy trucks with back plate lifts is usually necessary, this in order to ease deliveries of various industrial equipment and products. Obviously this calls for appropriate door heights and a levelled entrance, with a minimum of difference in heights, as well as a floor that can sustain heavy loads and an anchoring of various equipment by means of expansion-shell bolts. This might seem to be obvious user (tenant) demands but according to the author these have been neglected in at least three cases of projection of university buildings. Access to high-pressurised water most also be considered in order to clean out the premises at regular intervals.[5]

4 The ease of access by means of vehicles, as well as convenient parking places for temporary visitors, are important factors in order to facilitate fetching and delivering of various goods during more intensive periods of practical work.

5 Security aspects must also be considered. In some cases the industrial partners might have new products or data that must be protected. Some universities in Sweden have specially designed insurances to cover theft but they only cover the hardware, not the work represented by e.g. data. However, the insurance terms could be used for stating the level of security.

In this context it should be noted, that the way of transition of research results argued in this article, will most probably result in an intermittent use of the experimental areas which might provide a false announcement as if the premises are not used at all.

According to al of the authors' experiences concerning building design and construction within the university, the importance of user participation in the building projection must be underlined and by means of formalised methods (e.g. Wätte and Cassel, 1989; Bergvist, 1994). Such formalised methods were to some extent used earlier than the responsible governmental authority (Kungliga Byggnadsstyrelsen) in Sweden was answerable for governmental buildings (see e.g. Byggnadsstyrelsen 1979).

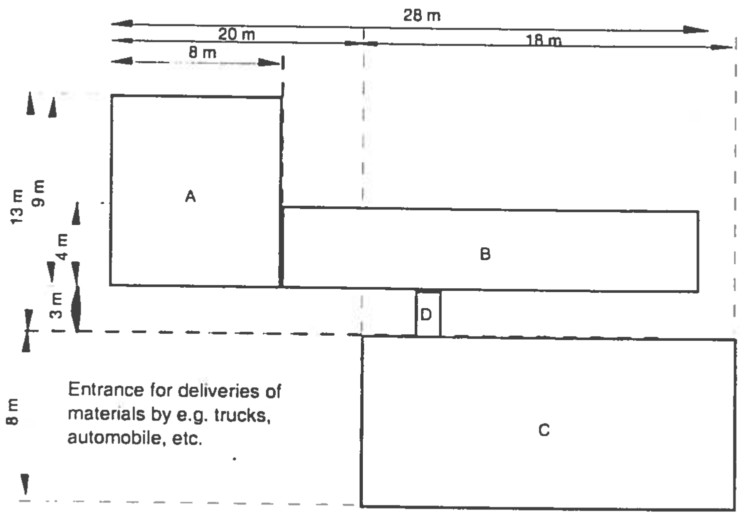
The critical function of a, correctly designed and utilised, building programme constructed and communicated in the early phases of the projection must be recognised by all persons involved. Such a programme constitutes the platform for the later phases in the projection. It has also proved important to include all costs in this programme, even those not directly related to the building in an early cost estimate. This might for example comprise costs such as rent for temporary premises for the user who has to move around on the campus, cost for lost earnings due to discrepancies in the provision of premises, etc. The building procedure must be, as is the case in extensive projects within e.g. the automotive industry, continuously checked by a number of checkpoints ("gates"), defined beforehand. No further work within the building project ought to proceed until the agreed criteria at the checkpoint are fulfilled (Engström et al. 2001).

The ways of providing premises within the university are definitely questionable – the recent experiences from the authors relate to, as is mentioned above, three cases. In each case the user demands have been neglected and in some cases the user has been forced to finance his/her own

[5] In a newly designed laboratory at Chalmers University of Technology (see figure 4) one of the authors has fixed threaded flanges, forming a net of quadrants by 2.40 X 2.40 metres in the ceiling to be prepared for fitting equipment, not yet decided (electric hoists, balancing blocks, etc.).

engineering and architecture expertise in order to have some influence on the buildings projected, all in conflict with the university property manager. This might seem like severe statements, but according to the authors' professional work, involved in several large industrial projects embracing building projections, these experiences deserve criticism.

This state of affairs is basically due to a deficient user dialogue between the persons responsible for the specific building project and the university's property manager. All these idiosyncrasies emanate from the property owner (i.e. the university), whose qualifications as a customer, responsible for defining the building facilities have proved to be low. Nevertheless the resulting building costs are perplexing (see e.g. Lundholm 1996). Consequently the extreme rent, exceeding 2 700 SEK per square metres and years for premises which by no means are suited for the user (comparable premises rented outside the university would call for one fourth of up to half this price). For a more detailed description of these three cases of the idiosyncrasies of building projections within the university see Engström et al. (2000).




A = Offices of various sizes from one up to three persons.
B = Combined office and laboratory, i.e. space possible for light mechanical and electronical work.
C = Laboratory for heavy mechanical work but also possible to use as an office.
D = Glassed crossing between the building containing offices and the building harbouring laboratories. This was necessary since old buildings were utilised and the vibrations from the metal cutting machines are not allowed to affect the work in the other building.

Layout Codification

Figure 4. Layout of the new premises at Chalmers University of Technology, School of Technology Management and Economics; in this case the office and experimental laboratory for Materials Handling Research Group at the Department of Transportation and Logistics. These premises have an internal flexibility which is gained through (1) the combined office and laboratory which could be utilised either as office or alternatively as laboratory or as a combination thereof and (2) possibilities to cut off at various positions along the line from A to C and to create offices form both ends. The use of (3) various sizes of office rooms, in one case a room less than 10 square metres for temporary work and guests, also improves the flexibility. Note however, that this has by no means been a smooth design process. Still some severe restrictions exist since the building permit does not allow regular transports to the experimental laboratory.

## 6 CONCLUSIONS

To summarise some of the aspects touched upon above, in order to speed up the implementation of research results within the society, there is a call for what may be coined as a "crosswise legitimatisation" between practitioners and researchers. This implies that both the industry and the academy ought to recognise the need of iterative and combinatorial processes with parallel activities, comprising an overlap between problem areas treated by the practitioners and researchers.

In some cases this involves an alternating work process between industrial premises and university building facilities and thereby a demand for new aspects – other than those traditionally considered by the persons responsible for the specific building project and the university's property manager - to be integrated into the university buildings. Today these building designs are restricted by various internal factors such as extremely high rents, deficient user dialogue, property owner whose qualifications, according to all of the authors' experiences, are questionable.

In order to facilitate the generation of knowledge, the co-operation between industry and senior researchers must be carried through based on agreed principles and based on long-term personal relations. This is quite a different approach than e.g. the traditional evaluation research usually comprising extensive, describing elements of the present situation within the industry. Appropriate building facilities will, due to the arguments brought forward in this article, in the future prove to be critical for the university in a way that has not been fully recognised.

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A common misinterpretation emanates from appointing natural science as synonymous with engineering and technology. By putting engineers and technology into a natural science context and paradigm, one neglects to accept engineering as a constructive, normative phenomenon. Usually this phenomenon is a multidisciplinary synthesising process, with vital entrepreneurial dimensions, utilising modern knowledge in for example social sciences, systems and behavioural knowledge, either collected from scientific knowledge or from practical experiences. An engineer must have some sort of overview in order to succeed, to materialise ideas and concepts while the extreme cultivation of "true science" leads to fragmentation. This is especially true if personal academic merits within the mother-discipline are prioritised.

It may be argued that the type of research referred to above ought to be carried through in form of cross-fertilisation between selected complementary scientific disciplines, represented by senior researchers organised as a parallel and iterative process, based on joint-venture coalitions with the industry. This way of crosswise legitimisation for transition of knowledge back and forth between practitioners and researchers calls for other building facilities than available today. Thereby totally new preconditions for a fruitful "research and development work" are created. It should also be noted that it is desirable to involve senior researchers that have been acquaintances for a long time, since "personal chemistry" is indeed important. Such acquaintances are successively becoming more important.. There must be a readiness for this with the decision-maker and research foundations or certain problem areas and/or researchers will cease to exist.

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