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Tracking of Building Materials on a Building Site; Use and Visual Display

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Preface

This Master's thesis paper "Tracking of Building Materials on a Building Site, Use and Visual Display" is made in connection with TPK4920 Project and Quality Management, Spring 2016, at the Department of Production and Quality Engineering.

This is a 30 credit reduction requirement for a 2 years Project Management Master's Degree at the Faculty of Social Sciences and Technology Management, Department of Industrial Economics and Technology Management at the Norwegian University of Science and Technology (NTNU).

In cooperation with the research project SpeedUp, the Master's thesis paper's main objectives are:

- Identify possible signal sources from all possible AIT's (Automatic Information Technologies) on building materials to track these (in real-time) to, and at, a case-study building site: Campus Ås, Norway, used by the independent contractor BundeBygg AS to build Råbygg part 1&2, and see if new signal solutions can be put into place in the future.
- Observe project planning routines and see how to match this information up in connection with the information captured from the materials used (real-time).
- Try to utilize this information and design an App, the BFGApp, that can maybe help achieve reduced total project time by reducing the (case study's) execution phase time. This could also affect future projects, by creating a documented trail for how the material is utilized, and therefore make knowledge transfer to other projects easier.

Excerpt from Richard Feynman's "New Textbooks for the "New" Mathematics, Engineering and Science volume 28, #6, March 1965 states: **"The real problem in speech is not precise language. The problem is clear language. The desire is to have the idea clearly communicated to the other person."** As I try to aspire to Richard Feynman's words, reality is that it is very is difficult to translate an idea to other people. But with this paper I at least try to convey the idea behind the BFGApp.

In making of this thesis paper, I have been fortunate to meet many people that deserve thanks; **SpeedUp**: Project leader Agnar Johansen, Siva Ekambaram, **BundeBygg AS**: Dept. Chief Project Design Iver-Erik Kylling, Project leader Campus Ås Lars Murstam, Head of IT development Petter Sponberg. **All the employees** at the **suppliers** that took time to answer my questions. The many people with **Statsbygg**. **Software Engineer** Julie Frøseth has been a good voice into the world of Apps. From **IPK&SpeedUp** Professor Nils Olsson and all the others that are involved with the Master students.

For a patient and calm mind, **supervisor** Professor Bjørn Andersen, IPK deserves many, many thanks.

Abstract

This Master thesis paper is made in connection with the research project SpeedUp, which main objectives are to develop strategic, tactical and operative measures to reduce total project time on big, complex building-and construction projects in Norway. The main objectives for this thesis paper are: to identify possible signal sources from all AIT's (Automatic Information Technologies) on building materials to track these (in real-time) to, and at, the case-study building site Campus Ås: project owner/builder is Statsbygg (The Norwegian Directorate of public Construction and Property agency), used by the independent contractor BundeBygg AS to build Råbygg part 1&2, and see if new signal solutions can be put into place in the future. To observe project planning routines and see how to match this information up with the real-time information captured from the AIT's on the materials used. And to try to utilize this information and design an App, the BFGApp, that can possibly reduce total project time by reducing the (case study's) execution phase time by using the real-time AIT data available. This could also affect future projects, by creating a documented trail for how the material is utilized, and therefore make knowledge transfer to other projects easier.

AIT's found were GPS tracking on ready-made concrete trucks which can track the concrete from the production area till out-pumping/use at the site, Barcode tracking for rebars, and the rest of the main building materials were put in the group "AITPicture", were one have to use a picture of the object as tracking. AITPicture can't immediately call up information from the the material since it is not connected to any information, except being recognized as a type of material. Future AIT's could include RFID tags with censors to measure (humidity, temperature, other) in the concrete to track the curing process, and RFID tags (passive, in-between) to track most of the other materials on the building site. This because the RFID tags don't need a straight line of sight to transfer information, the tags have a much longer wear and tear timeline than for instance Barcodes, and a portal on the site entrance would gather the information when the material is delivered.

The main project planning Statsbygg is doing, includes Gant diagram in MS Project for weekly development/progress, general meetings, safety rules framework (HMS), meetings and inspections on the site, to keep everyone in the loop: the Web hotel solution Interaxio for answers and questions, BIM to visual and technical use (at all levels from the HQ to the BIM-kiosks at the site). Interaction between the three levels were through contracts/bids, e-mails, phone, meetings and FTF communication. They use BIM, Interaxio, MS Project and Excel as systems. The independent contractor BundeBygg AS uses Viscenario to make deviation reports. The communication between BundeBygg AS and the suppliers were made mainly by meetings, phone and confirming order e-mails. The material departure from supplier production site is, depending on the AIT solution of the company, either made by following a GPS signal, scanning out from production site and onto a truck, or packing lists, till only waybills. The logistics were made by several different solution, from own trucks, to hired companies. The common ground was that all the drivers needed to do a safety class before entering the building site, making this a deciding factor in the shipping planning.

The BFGApp (BigFriendlyGiantApp) idea was to easy visualize the material utilization progress (real-time vs planned material use) as a part of the building process-production, so trends and progress could be used to create a feedback loop. This feedback loop could be used to adjust, change, make production processes more refined, and by this maybe reduce the execution phase of the project. In addition, a documented trail could make knowledge transfer easier to future projects and therefore maybe reducing the planning phase time. This idea was found to be difficult in practice, it is not enough material planning up front that the App could utilize. At present time, it is solved by expanding the App functions by routing the ordering of the materials though the BFGApp. This provides a "planned" material usage before the actual use and can be used together with the AIT's data to get real-time progress reports. The App is therefore divided into 4 parts; App Scan-Take picture, App Order, App Supplier and at last App Status. This new BFGApp could then be used as the original idea was intended (via a more complex function and design) in addition to centralize much of the information that dealt with all material ordering and use. This can also be used to get financial real-time progress, be in education (games), create documentation trails and can make knowledge transfer between projects easier, among some.
Much more work is remaining; program the structure for the BFGApp so it can be a functional App, tests it with the available data and further development is needed.

Abstrakt

Dette Masterprosjektet er skrevet i samarbeid med SpeedUp, som har som hovedmål å utvikle strategiske, taktiske og operative tiltak som kan redusere total prosjekttid på store og komplekse bygge- og konstruksjon prosjekt i Norge. Hovedmålene til Masterprosjektet er: å identifisere mulige signalkilder fra alle AIT'er (Automatisk Informasjonsteknologi) av byggematerialer til bruk av sporing (i sanntid) til og på en kasusstudiebyggeplass, Campus Ås: byggherre er Statsbygg (Statlig forvaltningsbedrift), brukt av den uavhengige entreprenøren BundeBygg AS til å bygge Råbyggdel 1&2, og se etter nye signalløsninger som kan settes inn i fremtiden. Å observere planleggingsrutiner og se hvordan denne informasjonen kan brukes sammen med sanntidsinformasjonen fra AIT'ene på byggematerialene som er brukt. Å prøve å utnytte denne informasjonen og skape en App.; BFGApp., som mulig kan redusere total prosjekttid ved å redusere (kasusstudie) gjennomføringsfasen ved å bruke sanntids AIT data tilgjengelig. Dette kan også påvirke framtidige prosjekt, ved å dokumentere hvordan materialene er utnyttet, og derfor kan kunnskapsoverføringen til andre prosjekt bli enklere.

AIT signalkilder funnet er GPS sporing på ferdigbetongbiler, som kan spore betongen fra produksjonsområde til utpumping-bruk på byggeplassen, Barcodesporing for armeringsjern, og resten av de hoved-byggematerialene ble satt i gruppa AITBilder (AITPicures), hvor en må bruke et bilde av objektet som sporing. AITBilde kan ikke med en gang bringe opp informasjon siden den ikke er koblet til noe informasjon, unntatt å bli gjenkjent som et type material. Fremtidige AIT løsninger kan inkludere RFID brikker med sensorer som kan måle (fuktighet, temperatur, andre) i betongen for å følge herdeprosessen, og FRID merkelapper (passive, imellom) for å spore de fleste andre materialene på byggeplassen. Dette fordi RFID brikker-merkelapper trenger ikke en rett linje sikt for å overføre informasjon, brikkene-merkelappene tåler slitasje bedre enn for eksempel Barcodemerkelappene, og en portal på byggeplassinngangen kan registrere signalene når materialene blir levert.

Hovedplanleggingen Statsbygg gjør, inkluderer Grant diagrammer i MS Prosjekt for ukentlige oppdateringer-framdrift, møter, sikkerhetsrammeverk (HMS), møter og befaring på byggeplass, for å holde alle deltagere oppdatert: Web-hotell løsningen Interaxio for spørsmål og svar, BIM for visuelle og tekniske løsninger (alle nivå fra HK til BIM-kiosker på byggeplass). Samspillet mellom de tre nivåene var gjennom kontrakter/bud, e-mail, telefonsamtaler, møter og FTF kommunikasjon. De bruker BIM, Interaxio, MS Prosjekt, og Excel som systemer. Den uavhengige leverandøren BundeBygg AS bruker Viscenario til avviksrapportering.. Kommunikasjonen mellom BundeBygg AS og leverandørene ble gjort hovedsakelig mellom møter, telefon og bekreftende e-mailer. Materialavgangen fra leverandørproduksjonsområde er, avhengig av AIT løsningen for selskapet, gjort ved å følge et GPS-signal, skanning ut av produksjonsområdet til fraktbilen, til bare et fraktbrev som følger med bilen. Logistikken ble løst på forskjellige måter, fra egne lastebiler til leiet biler fra fraktselskap. Den felles for dem alle, var at alle førerne som ankom byggeplassen må ha et sikkerhetskurs før de får komme inn på selve byggeplassen, noe som gjør dette til en bestemmende faktor i fraktplanleggingen.

BFGApp. (BigFriendlyGiantApp) ideen var å enkelt visualisere materialbruk fremdriften (sanntid vs. planlagt materialbruk) som en del av byggeprosessen -produksjonen, så trends og framdrift kunne bli brukt til å skape en tilbakemeldingsloop. Denne tilbakemeldingsloopen kunne bli brukt til å justere, forandre, gjøre produksjonsprosessen mer raffinert, og ved dette kanskje redusere gjennomføringsfasen av prosjektet. I tillegg, dokumentasjon av materialbruken kan gjøre kunnskapsoverføringen lettere til framtidige prosjekter og derfor kanskje redusere planleggingsfasetiden. Dette ble i praksis vanskelig, det er ikke nok materialplanlegging før bruk som Appen kunne utnytte. På nåværende tidspunkt, er det løst ved at Appen funksjoner ble utvidet til å omdirigere bestillingene av materialene gjennom selve BFGAppen. Dette gir en ”planlagt” materialbruk før et faktisk bruk og kan bli brukt sammen med AIT’s data til å få en sanntidsframdriftsrapport. Appen er derfor delt inn i 4 deler: App. Skann og bilde, App. Bestilling, App. Leverandør og sist App. Status. Denne nye BFGAppen kan da bli brukt som den originale ideen var tenkt (men med en mye mer kompleks funksjon og design), og i tillegg sentralisere mye av informasjonen som omhandler all materialbestilling og bruk. Denne Appen kan også bli brukt til å få finansiell sanntidsfremdrift, bli brukt i undervisning (spill), dokumentere historie og kan gjøre kunnskapsoverføringen mellom prosjekter lettere, for å nevne noen.

My mere arbeid gjenstår, programmering av strukturen til Appen så den fungerer, testing med tilgjengelige data og videre utvikling av produktet.

1. Introduction

This paper is a Master thesis done in connection with a research project called SpeedUp. This research project is funded by the Research Council of Norway, Prosjekt Norge and several industrial partners (www.prosjektnorge.no). The idea, or vision, of SpeedUp is to "reduce the total project time in the industrial partner's big, and complex, building- and construction projects with 30-50 % compared with/to the 2013 level". Main objectives are strategic, tactical and operative measures. One of the focus areas in SpeedUp is Real-time process overview. This Master thesis objective, or strategic purpose, consists of three parts within the Real-time process area (big data identification and capture):

- Identify possible signal sources from all possible AIT's (Automatic Information Technologies) on building materials to track these (in real-time) to, and at, a case-study building site: Campus Ås, Norway, used by the independent contractor BundeBygg AS to build Råbygg part 1&2, and see if new signal solutions can be put into place in the future.
- Observe project planning routines and see how to match this information up in connection with the information captured from the materials used (real-time).
- Try to utilize this information and design an App, the BFGApp, that can maybe help achieve reduced total project time by reducing the (case study's) execution phase time. This could also affect future projects, by creating a documented trail for how the material is utilized, and therefore make knowledge transfer to other projects easier.

This Master thesis paper is focusing on giving the building materials on a building site a voice by designing an App that can show real-time building progress update, which then can be used to possibly produce time reducing effects. When the study started, it became clear that there is very little information and articles about tagging, tracking and use of building- and construction material on a SITE (and the material transfer from the production area) to be used in real-time progress. There are an abundance of literature/articles that describe Supply Chain Management solutions and problems related to tracking of clothing, cars, food and about every other item, but not in this relation. There is also many studies that predict that AIT's should get their place in this particular area, but it has not become reality. This creates, among other things, problems in giving a real-time material update while underdoing the execution phase of a project. This means that the observations during the period I have worked on this, will be a part of the forming of the conclusions.

But if one can track building materials in real-time, to observe building progress, one can create a feedback loop. This feedback loop can change how materials are being planned, and used, in the building progress. As a result it could change processes that are creating problems (delays, wrong and late information, cooperation), and therefore reduce the building, or the execution phase, time. This feedback loop theory has given positive results by giving objective information in real-time that give people an opportunity to change their behavior, for instance, in reducing speed when driving (Goetz, 2011, p.1).

Initially, the thesis planned to compare a premade building progress plan to signals captured by RFID-sensors (radio frequency identification) attached to materials on the building site, where the results displays as a red or green signal in an App on a handheld device. But during the project, it became clear that to give a voice to as many materials as possible, it was necessary to reconsider all possible automatic information technologies (AIT), and automatic data capture (ADC). This can consist of, but not restricted to, Bar codes (2D/3D), Radio frequency identification (RFID active, passive, in-between), Radio frequency data capture (RFDC), Real-time location systems (RTLS), Satellite tags/GPS, "Microelectromechanical" systems (MEMS), Contact memory buttons, biometric, access cards, and optical character recognition (OCR) (Jones & Chung, 2011), video, and pictures. As Jones and Chung, 2011, p.33 so appropriate say, "…the strategy purpose or operational requirements should drive the technology chosen. The technology should not be chosen based on technical bias". Video and pictures will for this purpose be categorized separately, since they are not giving individual numbers, but are placed in a group; AITPicture.

2. Theory

When undertaking a project like this, which cover a wide range of area; the case study building project (the project planning, the layers for communication and how this is done practically), AITs and their function, materials and supplier routines, how to design an App and how it supposed to flow, the App's visual appearance, what is the features one need and how can it be done? Since the AITs are one of the major features, it is naturally to dig deeper into their features and problems. In addition some supply chain management theory is shortly covered.

Some of the tracking devices used for the purpose of this paper is using technologies that have been on the market for a long time. Modern barcodes (1D), inspired by Morse code in 1948, started out as "bull's eye bar code, but changed later to a rectangular bar code. It is read optically (laser), and gives specific information, which can be read from the black parallel lines and their spacing (Weightman, G., 2015). To increase the information capacity while using less space, 2D codes were developed (stacked, matrix). QR is a 2D matrix code, which is made up of dark and light squares. To scan the symbol, a two-dimensional imaging tool, like a camera, is needed (http: www.aimglobal.org).

RFID technology, which is going to be proposed to follow processes and materials in the 3.d objective, has been on the market since World War 2. This technology tracks and identifies objects using radio waves. RFID tracks, among others, global supply of consumer goods and military equipment (Fescioglu-Unver, Choi, Sheen, & Kumara, 2015, p. 1). RFID with sensors are being used to monitor/control the temperature in cold food/supply chains (food, chemical, pharmaceutical) (Fescioglu-Unver et al., 2015, p. 6). Supply Chain Management challenges consist of problems like theft, excessive inventories and lead-time that are too long (Fescioglu-Unver et al., 2015, p. 4). Using RFID to increase traceability and efficiency through automation can solve these problems. Asset tracking by adding Geographical Information Systems (GIS) and Short Message

Systems (SMS) can decrease the lead-time; RFID with wireless options can give Lean and Just-in-time production (JIT), and Work-In-Progress (WIP) inventory overview can give better systems agility and better inventory handling. RFID can also be used in Product Lifecycle Data Management.

In the building business RFID can be placed on materials. This can track their way from the production area to the building site, which can for instance hinder use of counterfeit products (Asanghanwa, 2007), track building progress on the building site, and can be used when problems appear when building/product is finished.

RFID with sensors, which measures temperature has been placed in concrete to follow the concrete curing conditions. This can give signals to when the concrete work forms can be removed. It can also be used to observe the maximum temperature for the curing process to adhere to quality requirements. A Swedish field study (Sjöberg & Gerstig, 2009) transferred signals from RFID sensors in concrete to the readers by transmitter signals; 868 MHz (radio signal), 125 kHz (magnet signal) and a mix of these. Some problems were observed (software problems in reader, battery length, size and placement of sensors, different signal strength in fresh poured concrete vs. older, distance from reader to sensors), but the sensors transmitted similar temperature profile (Sjöberg & Gerstig, 2009). Other sensors systems can measure humidity, chemical density, and by using impedance change one can measure strain and displacement (modified comb-like NSRR (nested split–ring resonator)) and can be used to wireless monitor structural health (SHM) in reinforced concrete elements (Ozbey et al, 2016 #19).

Global Position Systems (GPS) works with satellites and receivers, and calculate the distance between these. With each calculation possible positions gets narrowed down till one remains and this process is managed by the position module in the system (Fescioglu-Unver et al., 2015)

The building industry has not been able to reap the full experience learned in the consumer goods area for several reasons. One main factor can be that building sites are not stationary like a warehouse for storing consumer goods along a set logistic route (urban, countryside), and can have difficulty gaining access to standard info systems. Chen and Kamara (2011), p.777 say, "Ineffective information communication on construction sites can lead to the neglect of important issues that require a quick response, which may result in on-site decisions being deferred". Problems with price (system, reader, tag, sensor), accuracy (GPS errors), how to get signals through from sensor to reader (distance, orientation, position, collision of signals), how to tag building materials and equipment can be other reasons ((Fescioglu-Unver et al., 2015; Li et al., 2015). Physical constraints like weather (temperature, humidity) (Chen & Kamara, 2011, p. 778), site layout (surface conditions-dust, hauling distance, neighborhood, and topography) (Popescu, Phaobunjong, & Ovararin, 2003, p. 137), and many different materials (corrosive, bulky, small volume) and special equipment can be other reasons.

Some of this has changed with increased wireless speed and mobility of info systems by portable devices. A combination of systems transferring signals over different bases using different methods (interoperable, high-bandwidth, high-speed private/public infrastructure-based wired and wireless telecommunication networks etc.) can help keep building sites online and updated (Musa, Gunasekaran, Yusuf, & Abdelazim, 2014). New data systems (Hadoop, NoSQL databases) that can handle enormous volumes of big data; preprocess (data cleaning, integration, transformation, reduction) and analyze the incoming signals (Philip Chen & Zhang, 2014) has made the use of big data much easier. Sensors, systems and gathering of the data are constantly refined and this will hopefully make it cheaper to both gather and analyze data. The predictions for 2016 is that the big data is old, while algorithms are in and to be used to give answers to what actions should be taken based on the processed data. Fog computing or analytics, where the data from sensors get produced in real-time, so smart machines can carry out fragments of the analysis locally and then send the processed data further to save time and money (Rijmenam, 2015). This will make it easier to track materials coming to a site, and used in production on site, making a complete, real time logistics and production (building/construction) line. The results can be a part of the feedback loop and used to take actions if needed.

3. Material and Methods

The strategic purpose of this paper has 3 parts, where the two first parts are getting information from different perspective of the case study at Campus Ås's building process.

The backdrop of the thesis is the case study; the building of the structural work on the veterinary buildings at NMBU (Råbygg part 1 and Råbygg part 2), within the time frames and requirements that are decided up front through contracts and agreements, at Campus Ås outside Oslo, Norway. The main participants in this study are builder or project owner Statsbygg (byggherre), which is the Norwegian Directorate of public Construction and Property agency, and BundeBygg AS, which is an independent contractor in the construction business that specialize, among other things, in in-situ concrete. BundeBygg AS is doing what is called an execution contract (utførelsesentreprise) for the concrete work at Campus Ås, and the time frame is planned to be from Fall 2015 and continue through 2018. The building is around 60.000 square meter, and it contains about 42.000 cubic meter in-situ concrete, 14.000 ton prefab concrete and 1330 "constructionsteel".

This is done, on one side; by having BundeBygg AS's suppliers deliver materials in a timely manner and the building crews utilize them following a preset plan at the Campus Ås building site. On the other side, project planning on the building site is being done after preset plans, and building execution as the building process progresses, which decide the direction and progress of the buildings during execution depending on the condition on the site.

The first part of this thesis paper is to examine the automatic information technology that is connected to the delivered building materials to make it possible to track it in real-time. This was done by observation on the building site, meetings with the project management team on the site and headquarter, and a 5 set of questions to the suppliers of the materials. Most questions were done by phone, but the supplier outside Norway was done by e-mail. The in-situ observations were done during two short periods during spring 2016.

The second purpose was to observe planning routines at BundeBygg AS, in the main headquarter and in-situ on the building site. Statsbygg was part of the more overall planning as the main project owner. This observation was also done in the same time periods as the first part of the objective. In addition it has been conversations and meetings over the phone, mail and Skype.

The third part was done by trying to utilize the data gathered to develop an App that could give the wanted results. Discussions with a Software Engineer; Julie Frøseth, were done on two occasions. An App used for this purpose must be easy to use at the construction site, and on the same time give enough info to show a real-time progress and deviation that can be used to do a change. It needs to be made for something that most people carry at a construction site, and be mostly self-explaining. To try to figure out different AIT solutions (RFID sensors that measure temperature and humidity in concrete e.g.) for the future, there were meetings with the head of the IT-department at BundeBygg AS and meetings with sensor solution systems companies. Among them, two meetings with APX Systems which sells system solutions, innovation and hardware to different business areas. The Mock-Ups were done in Balsamiq Mockups 3.

The main materials in this particular building process are:

1. Ready-made concrete delivered by concrete trucks from the concrete company "Suppler X". This company is owned by an *Italian company.*
2. Rebar (reinforcement products) from Celsa Steel Service AS. This is a company which produce steel in all the Nordic countries, and is a part of the *Spanish Celsa Group*
3. Constructive steel structures, are made by EMV Construction AS. It produces special ordered stairs and railings, steel constructions, doing steel processing, and sell technical solutions to rehabilitation projects. This is a *Norwegian owned company*.
4. Void former modules and premade steel rebar cage (Slim-Line cage module) is supplied by Cobiax. This product replaces concrete with hollow void formers in special reinforced rebar mesh. It reduces the weight and volume used in the in-situ concrete slabs. This is a *Swiss company*.
5. Ischebeck Nordic AS delivers concrete formwork equipment, trench-lining systems, geotechnical solutions among others, and is a daughter company of the *German Friedr. Ischenbeck GmBh*.
6. Hansmark is delivering concrete formwork equipment and general building equipment. This is a *Norwegian owned company*.

   In addition 2 other companies are delivering misc. equipment to the site.

Most of the suppliers were asked 5 short questions. The first one, Q1, tries to determine what AIT's are being placed on the building materials they are selling. To see how the total "tracking" or documentation of the material were done, Q2 and Q4 were added, this include ordering, shipping bills, and interaction between the buyer, BundeBygg AS, and the supplier. Some of this information is used under project planning and methods further down in the paper. In addition, it was of interests to see how the logistic overview was from the building production area to the building site, and Q3 and Q5 would highlight this.

The main idea behind the questions was if the BFGApp should manage to function in the way it was initial thought, the whole supply chain had to be included from ordering, production of material till utilization on site, and therefore have an AIT solution, which the App could use. By asking these questions, the mapping of how the different companies solve tracking of orders, materials and logistic part hopefully became clear. As time was of essence here, in addition to the changed requirements for the App, there was only time for Low Fidelity Mock-Ups, and no programming for the App itself.

Q1.
How were your materials marked when you shipped them from the production-storage area? Barcode, or other AIT's?

Celsa Steel Service: Barcode (1D) on bundles and pallets. Implementing QR (2D) in company, but not on Campus Ås yet.
EMV Construction: Steel gets marked with a sticker containing serial/unique number (order number and C-number). This number can track the steel back to production site of steel. (Picture AIT).
Ischenbeck: No tracking devices, only on material that are lifting, these need certificate numbers (Picture AIT)
Cobiax: Paper tag showing the type of material (Picture AIT).
Hansmark: No tracking systems, only visual. Each formwork company has different equipment and this is used as tracking (Picture AIT).

Q2.
How did BundeBygg AS communicate with you as a supplier; by using a computer system, by phone, by e-mails, other, to order the supplies?

Celsa Steel Service: Order steel from drawings, and cut and bend go to the order office, while certain steel sizes (12 mm, 16 mm) and volumes (30 tons and above), get ordered by phone to a dedicated person at the company.
EMV Construction: Here the communication is by phone and e-mail. In addition they are added to Interaxio and can follow the interaction there.
Ischenbeck: Start-up meetings together with BundeBygg AS. Ischenbeck is projecting AutoCAD drawings. After BundeBygg AS accept the drawings, assembly lists and material lists are submitted.
Cobiax: Communication by phone and e-mail.
Hansmark: Planning meetings with BundeBygg AS up front. The order is phoned in and confirmed by e-mail.

Q3.
How is the building materials registered when shipping it out from the production-storage area, did you send a shipping waybill only or did you register the materials through other intern systems (scanning out from storage, in on truck)?
Celsa Steel Service: All material is scanned out of storage and into the shipping truck.
EMV Construction: A waybill is made when the construction is leaving the production area.
Ischenbeck: Waybill is made after materials have been selected and put in boxes using order lists. The boxes get marked with ties.
Cobiax: Shipping waybill is made for every truckload; the quantities are confirmed by paper documents and then sent to the back office to be confirmed with internal database.
Hansmark: The building materials are picked following packing slips, when leaving storage area.

Q4.
Did your company get instructions beforehand where on the building site (Campus Ås) the materials were going to be offloaded, or was that something that was decided on the site when delivered?

Celsa Steel Service: When order comes in, the place for off-loading is given.
EMV Construction: Since this is large and heavy construction material, much planning is needed up front how to get the materials to the construction site, and off-loading is also included in this discussion.
Ischenbeck: They get to know where to deliver beforehand, and where the cranes and lifting help is situated when the load is when they arrive at construction site.
Cobiax: The off-loading address was known up front, the offloading location was told to the driver on site.
Hansmark: Little unsure, but usually they know where the offload point is on the construction site, and where scaffolds are already in place for offloading.

Q5.
Did you use your own shipping system or are you hiring out the order to an independent shipping company?

Celsa Steel Service: Permanent, hired company for transport.
EMV Construction: Usually the company is using own shipping/transport, but in the case of Campus Ås, the construction materials are affected by size and weight, so it needs special transport.
Ischenbeck: Rent shipping transport, but drivers is required to take HMS classes to enter construction site.
Cobiax: Most of the time it is a shipping company, but sometimes clients organize own transport (EXW Germany)
Hansmark: Usually they hire shipping trucks, but in the case of Campus Ås, the drivers are required to have HMS classes, so in this case they use their own.

*SupplierX was not asked the 5 questions, but was treated separate since they use GPS tracking on their concrete trucks, not on the building material itself.
The two last of the 8 suppliers were not asked questions, as it was not really main material.

4. Results and discussion

4.1 Q1-Q5 supply answer overview

Supplier name	Building material	Q1/AIT's	Q2	Q3	Q4	Q5	Country origin
SupplierX	*Ready-made concrete, preset temp, volume and additions*	*GPS tracking of concrete trucks. Temp. confirm of concrete*					*Italian owned*
Celsa Steel Service AS	Reinforcement products	Barcode, 1D (Implementing 2D-QR barcode, but not in use at Campus Ås yet)	Orders from drawings, cut and bend go to the order office. Sizes (12 mm, 16 mm) + volumes, 30 ton and up by phone to dedicated person	All material scanned out of storage and into shipping truck.	When order comes in, the place for off-loading was given	Permanent (regular), hired company for transport	Part of Spanish group
EMV Construction	Constructive steel structures	Picture AIT Sticker containing serial/unique number (order number and C-number)	Phone and e-mail. Interaxio connected.	Waybill	Since this is large and heavy construction material, much planning is needed up front how to get to the construction site, and off-loading is also in this discussion.	Usually this company using own shipping transport, but in case of Campus Ås, the construction materials are affected by size and weight, so needs special transport.	Norwegian owned
Ischenbeck	Concrete formwork equipment and such	Picture AIT Only tracking if it is lifting material (have certification numbers)	Start-up meetings together with BundeBygg. Ischenbeck is projecting AutoCAD drawings. After BundeBygg accept the drawings, assembly lists and material lists are submitted.	Waybill Pick material after order lists (Marked materials with ties)	They get to know where to deliver beforehand, and where the cranes and lifting help is situated when the load is when they arrive at construction site.	Rent shipping transport, but drivers is required to take HMS classes to enter construction site.	Norwegian daughter company of German company
Cobiax	Void former modules	Picture AIT Paper tags describing what it is	Phone and e-mail	Shipping waybill. Paper document- into internal database	Off-loading address known up front, not off-loading point	Mostly shipping companies, but sometimes clients organize own transport	Swiss company
Hansmark	Concrete formwork equipment and such	Picture AIT Only visual tracking of equipment	Meetings with BundeBygg up front. Orders phoned in and confirmed by e-mail.	Material selected after packing slips.	Usually know both offloading point and scaffolding place for offloading	Mostly shipping trucks, but at Campus Ås, they use their own.	Norwegian owned

Table 1 on page above. Overview over main suppliers, building materials, answers to Q1-Q5, and company origin, that is used at the Campus Ås-“Råbygg 1 and 2”.

Table 1 gives an overview over the main suppliers, the building material delivered, answers to Q1-Q5 and country origin to the main suppliers at the Campus Ås building site.

The communication between the buyers (project managers, concrete team leaders on building site) and the concrete supplier is done on several levels, since the volume/quantity (coded activities on drawings and planned activity like floor in week Z) for a set period is being discussed days before to prepare the production facilities for the coming need of concrete. While the concrete team leaders on the building site are doing the direct calls to the production facilities shortly before the delivery when they are ready to receive concrete.

When undergoing big and complex projects like this, effective project planning throughout the whole project (idea, planning, execution, closure) is of vital importance. This includes effective communication between the participants so information is getting to the right person or team at the right time. To manage to include all levels in the planning and execution, it is necessary with many different “systems” and methods.

In this paper the levels of structure and communication are: 1. Level; Statsbygg as Builder-Project owner, 2. Level; BundeBygg AS as an independent contractor and 3. Level the suppliers to BundeBygg AS.A 4. Level is personnel, from regular workers, to drivers and other short time workers that are involved in the project.

4.2 Communication between the levels.

Statsbygg is setting the frame for planning, rules and behavior for the participants on the project. Bidding procedures and requirements, which decide the independent contractors (and then their suppliers), are decided from the initial project work done by Statsbygg. On Campus Ås, Statsbygg is using, as a way to involve all the participants, a Web-based solution: Interaxio where questions and answers are being exchanged. BIM (Building Information Modelling) is a visual model of the construction that can include timeframe and costs to reduce building errors and waste. BIM is distributed to all 3 levels if necessary, and used on the construction site. At Campus Ås it will be installed BIM-kiosks in the building “pit”, which will be used by workers at the site to aid in the construction. Meetings and safety inspections on the construction site, in addition to e-mail, phone and order/material lists for communication are also very important parts to keep all levels updated.

4.3 Systems between levels.

The Web hotel solution Interaxio for written communication between participants, BIM, for visual (in addition to material lists and changes), MS Project for project planning and progress, and Excel for more information if needed. Other, like waybills systems and the financial side, are not included in this thesis.

4.4 Internal communication BundeBygg AS.

BIM – Solibri (Campus Ås), architect drawings, order/material lists, Excel, MS project for progress and planning each activity week for week. Viscenario is an App that deals, among other things, with problems and faults in the construction, to report for repair or change and to have a documented/tracking of problem areas-objects (deviation reports). Meetings, discussions, e-mails and phone communication between the BundeBygg AS headquarter and the construction site.

4.5 Creating App for real-time progress

To change or improve any existing process or method, an overview over the process itself is first needed. This is done, in this case, by observing parts of the process to combine it to a total process: materials used, material tracking devices, logistic process methods for project planning for activities and routines, in addition to the communication and general project planning routines. Figure 1 tries to give an overview of the whole process that was being studied.

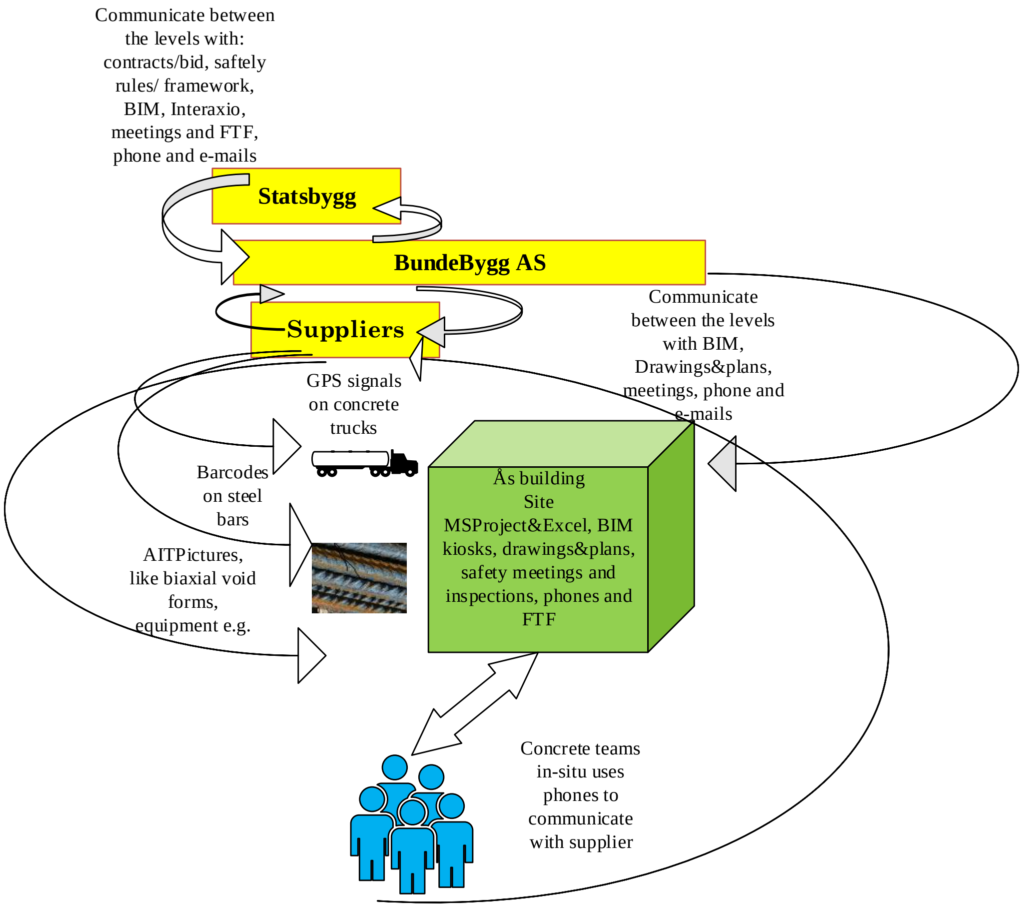

Figure 1. Shows an overview over the building process that was studied on Campus Ås.

When this overview is finished, the next step is to try to find ways to maximize the process/method. Real-time progress by using AIT's and their signals on building materials can be a way to use an objective source to get a quick overview over the progress on a construction site. See figure 2 for an overview over the different areas that are needed for the App development.

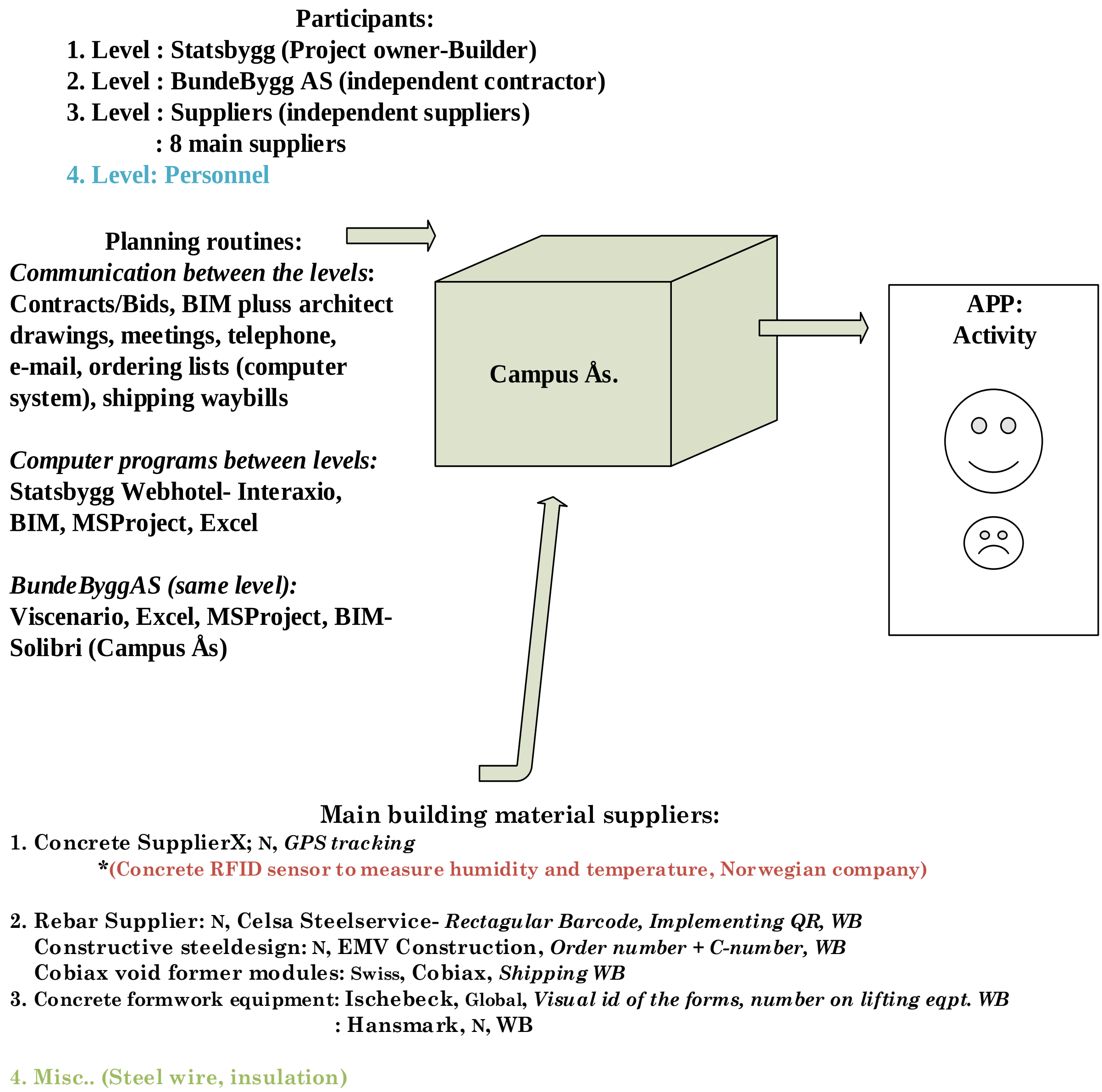

Figure 2. Shows the different parts that are used to create the App that can be used to improve/ change processes/methods on Campus Ås.

As shown earlier, the AIT currently arriving to the construction site at Campus Ås in connection with BundeBygg As building "Råbygg 1 & 2":

1. Concrete trucks, which can follow the concrete from concrete production site to construction site where the trucks off-load the concrete.
2. Steel rebar in different shapes and crates have Barcode (and is implementing QR on different construction sites)
3. For visual picture (AITPicture) progress one can use the Cobiax's void former modules after they are combined and put into the rebar cages.
4. Future use, RFID with humidity and temperature sensors.

It is possible to use RFID sensors, which measures temperature and humidity, in concrete to give a real-time picture of the concrete curing conditions. These signals could be compared with a generic curing graph, where temperature vs time is displayed. This can give the builder a signal if the process is not following the normal curing process, and it can be used to be sure the concrete has the quality it need before the concrete work forms are removed. In addition it create a documented tracking of the concrete curing for quality purposes in case problems happens.

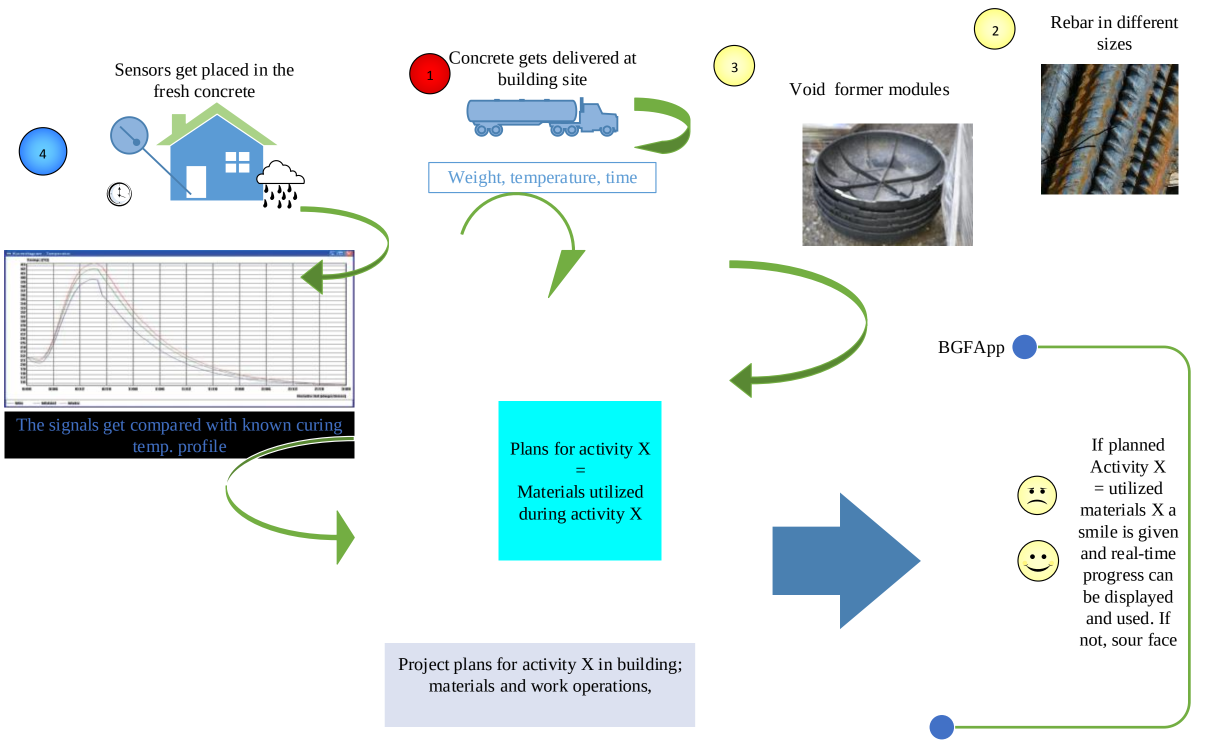

Figure 3. AIT signals today (and possible in the future) to be used to construct an App that takes real-time progress of materials use on the construction site and compared the earlier planned material use to get an deviation progress report.

Observations showed that there is no utilization by BundeBygg AS of any of the AIT's available on the building material arriving at Campus Ås construction site. The waybill/shipping bill does not go directly into a computer system that can utilize the information right away.

Among the AIT's found available on Campus Ås today, the GPS tracking of the concrete trucks are the better adapted for a building-and construction site. Barcodes (and QR) are all dependent of line of sight and can easily be washed away by weather, wear and tear. AITPicture can be used, but then one cannot rely on finding it by a tracking system, like a RFID tracking system can. The material can be tracked going through a gate on Campus, which can track all the RFID marked material that passes through. The materials can then be tracked all the way from the producer till the arrival at the site and then be tracked by scanning in the production.

At Campus Ås, BIM visuals and architect drawings with coding for different activity planning works side by side. As for structured activity planning (in such programs as Excel or MS project), it consisted of personnel scheduling and planning of activities like floors, concrete poles, and walls. It was not at such level that the App could use the data to compare the planned material progress vs the real-time data to get the App design that was planned from the start of the thesis.

The challenge then became to figure out a way to design the App to get the orders of the main materials into a system, so it could be compared with the AIT's signals (big data) that was arriving to the site and is being used in the building. This made the design a little more complex than originally thought. One idea came up during discussions on Campus ÅS, was to extract "planned" material use from BIM, but this was not, at present time, an idea that was followed further. Figure 3 shows how the BFGApp was thought to be working, but had to be adjusted for how projected planned activity material had to be gathered.

Instead, it was solved by doing the tracking of preplanned materials (amount, volume, or quantities) in the App by adding three parts. The App contains four areas; Scan and Pictures, Order, Status and Supplier. The data flow is shown in Figure 4.

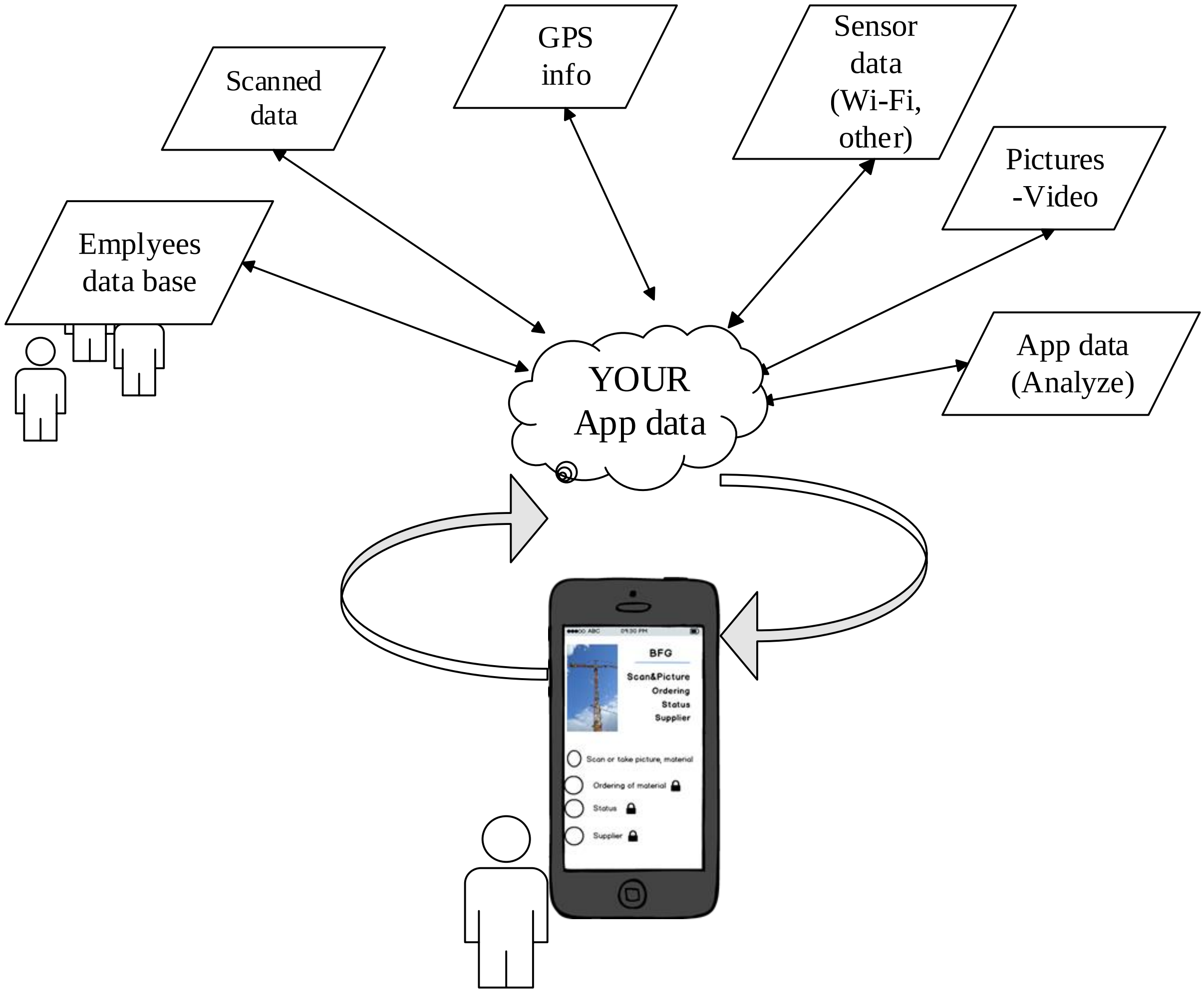

Figure 4. Shows BFGApp data flow.

The following Low Fidelity Mock-Ups are describing the main screens in the Scan&Picture, Order and Status area. There are no MC-Ups made of the supplier area, because there are more research needed to create this part.

BFG Scan: is an open function and is used by the building- and construction workers when material are arriving at the site (and being offloaded). It is then scanned by using the Barcode (rebar steel), other AIT methods, or take pictures (Cobiax's Void former modules) to get it into the receiving system. This will be part of the "planned" material area together with the BFG Order part. When the material are used in the building process, it will be scanned again to be part of the "utilized material part". It can then be compared with the "planned" to get progress and trends.

BFG Order: is a locked function and it is required log-in to place an order. This can replace the confirmed material order e-mails and/or phone calls that is done today. The concrete teams can order concrete through this and have a documented trail of the placed order and it can be used/combined with BFG Scan data to get "real" material volume/amount/number arriving the site and used in the real-time analysis. The rebar steel can also be ordered through this. Other material too, if necessary.

BFG Status is the original App idea. It is showing if the real-time progress vs. planned activity material use is either in sync or not. So the AIT's signals from BFG Scan&Picture and BFG Order would go into a base where they get compared with the different material use, orders and receiving material on the site.

Figure 5 shows Mock-Ups 1-12 in the BFGApp, and Mock-Up (MU) 1 is the main display on the BFGApp. It shows the user the different functions the BFGApp contains. MU 2 shows what comes up when choosing the button "Scan or take Picture, material". Here one choose the activity that the material are going to be used for. If the activity is not found, the "Contact the project leader" button can be used. After choosing an activity, to MU 3 pops up, which gives a choice of either using the scanning button or the camera button. MU 4 is confirming that the scanning or picture went through to the system and got saved.

MU 5 comes up when choosing the BFG Order function. This is a function that requires a log-in with username and password, to control use of the order functions (concrete, rebar steel, other). MU 6 pops up after the log-in button is pushed. Here 3 different choices are put up, but it can be reduced or increased material depending of needs. When material is chosen, MK 7 gives concrete choices (volume, temp, additions, other). For Order Steel choices (steel number/ volume, size, other) MK 8, and Order Other (select choice) MK 9. If want to combine the order to an activity, as one usually want, one can add MK 2 after the log-in and before the material chosen. In addition, if needed it could, after MK 7, 8, 9, be added a similar MK 4 to show the order, or that the product, is processed for confirmation.

The last four MK, 10-13, is what pops up when the BFG Status function is chosen A log-in function is required to access the Status function MK 10. When the log-in button is pushed, the activity choices are coming up with a smile/sour face next to it, MK 11.The next two MK 12 and MK 13 is showing the displayed progress (could be planned vs used materials, time vs used materials, e.g.). If the progress is not a smiley one, contact the project leader.

The BFG Supplier function is on the receiving end of the Order function, and will have to be adjusted to the needed functions there.

Figure 5. Shows Mock-Ups 1-12 in BFGApp, and its different functions/display.

5. Conclusion

The first part of this project was to find the AIT's that could facilitate the tracking of building materials arriving and being utilized at Campus Ås (BundeBygg AS). It is currently arriving 2 main materials (concrete, rebar) that can be tracked (GPS, Barcode), in addition to AITPicture material. The GPS signals (concrete trucks) give very concise data (Excel), and the rebar can be tracked by their Barcode, so both can be utilized by the future BFGApp. Currently there is no tracking of materials on the construction site itself by BundeBygg AS. In the future it is possible to add RFID tags, both to the curing of the concrete to get a real-time picture of the process (future quality demands, documented trail) and many other material used on the site. The control and entering of building material, personnel and vehicles at Campus Ås construction site, is extremely tight, therefore makes it possible to use all the AIT's tags arriving to the site by adding a portal for receiving signals when entering the building site when using RFID. It is worth to note that the two companies that have invested in tracking devices (GPS, Barcode) have foreign origin, while the other companies have not yet seen the possibilities with this logistic –and production tool. AIT's, possible RFID solutions, on the material could make it easier to track materials arriving, utilized and being recycled at the site. RFID tags/solutions don't need visual line of sight and the tags are much more resistant to wear and tear on a building- and construction site.

The second part was to observe and find what systems, methods and communication the project was using to get the execution on the site done. All the different ways of communication, and systems, make it hard to get a total documented trail of what is going on at the building site. I do think there are room for change in some processes by getting much of the activity gathered in a spot- in the BFGApp, and get documentation which can help with and improve communication and thereby use of time.

The third part was the use of the data gathered from the AIT's signals on the material used vs. project-planned material displayed in an App. As the initial idea had to be expanded to gather and centralize both planned and utilized material information, the App became more complex than the easy and clear idea envisioned up front. This could make it harder to use, which is against the vision of the App. The idea to get an easy and objective view from the material side of a building site to use in a feedback loop to correct problems area, became much more complex, but on the same time it could keep a much tighter documented trail on materials and its use. In addition to a much more complex BIM solution used on the building site, it could give valuable real-time information and track all the material which are, on a building site as big as Campus Ås, in huge amounts.

I do think there can be improvements in centralizing material and supplies like the BFGApp idea suggest, by observing both the communication between the participants in the project, the material tracking from start point to the utilization in real-time, and the synergy on the building site. To get the real-time data into use in a feedback loop by getting trends and visual display of material to correct processes could maybe save time. This App can also maybe be used in education by using either old or made-up data, as games for practice and to keep closer track of the economic side, which is hard in project where there are time lag for documentation. The documented tracking can also be used in further use of the building to do upkeep, and make the knowledge transfer to later projects easier. Much more work remains, mainly programming, testing and finishes on design on the App. In addition, testing on the construction site to see if the App is working as intended, to reduce the total project time, is needed.

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